Journal of the Forest Products Research Society

Vol. II, No. 2 June, 1952

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The Journal of the Forest Products Research Society is published at Madison, Wisconsin by the Forest Products Research Society, P.O. Box 2010, University Station, Madison 5, Wisconsin. Publication is quarterly - in April, June, September and November. Application pending as Second-Class Matter, April 1952, at the Post Office at Madison, Wisconsin.

Annual subscription rate, $ 8.00; Single copies, $2.00. Subscription is included at no additional cost with voting, associate and supporting memberships in the Society. Remittances should be made payable to the Forest Products Research Society.

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Machinery for Sanding Wood *

HUGH DE PREE, Works Manager, Herman Miller Furniture Co., Zeeland, Michigan

THE TWO TYPES

MACHINES used for preparing wood for finishing can be divided into two general groups, one of which would include general purpose machines, by which it is possible to sand different types of parts by just setting up or adjusting the machine. In this classification might come, planers, drum sanders and belt sanders. The other classification, special purpose machines, which are specifically designed to do a particular job. Such machines as the automatic turning sander, handle sander, and chair back sander come under this classification. Most of these general purpose machines and many of these special purpose machines have been used by furniture manufacturers for many years. For instance we have one drum sander which we bought at least 25 years ago and which we had to rebuild about three years ago. I think it's doing just about as good work as many of the new ones. Belt sanders, too, have been made over in their present form, so have shapers and routers. I hate to admit this but we also have an old sticker. I guess it's about 25 or 35 years old. I asked one of our men that operated it how long it's been there and he said he thought it was bought second-hand before he got there. But anyway, the markings on it show it was patented in 1911. We still have it on the floor even though we don't use it very often because we don't have much work for a sticker. However, in the last few months, we've about decided that we ought to have a high-speed moulder.

IMPROVEMENTS IN THE MODERN MACHINE

One of the major operational improvements, however, has been in the speed of the machines, particularly those that are used in finishing and in preparation for finishing. Shapers normally run around 3,600 to 5,400 rpm., we now find shapers running at 15,000 rpm., routers running 20,000 rpm., belt speeds on sanders have been increased quite a bit. One manufacturer recently estimated that in the last several years the belt speeds on their machines have increased by as much as 25 to 30 percent. Certainly, these higher speed machines have done a great deal to help us in our need for better finishing.

There have also been some major changes in the machines. Drum sander manufacturers are making some of them with four drums on the theory that they can do better work. There seems to be room for argument here, however, because some furniture manufacturers still prefer three drum sanders. One change which I think has been a big improvement is in the belt sander. Particularly in the stroke sander, we have changed from a hand-operated stroke sander, to the mechanical then to the hydraulic. I think most of us agree that the hydraulic does a better and a faster job than the other two. We have even advanced there to the double-belt hydrualic sander which can do both roughing and polishing operations, without removing the work-piece from the machine bed. Personally I object to this though because we believe in sponging between the two operations, and it cannot be done on such a machine. Our own tests, and we've made tests many times, show that you just can't get as good a finish if you do not sponge between the two operations. So we see that there have been developments. However, the question always comes to my mind on machinery of this sort, "Where do we go from here?"

PRODUCT SIMPLIFICATION WILL HELP

There is one advantage in making furniture of the types we do. I firmiy believe that all furniture is going to become simpler and simpler in design. If this is true, then all production men should jump and shout for joy, for it makes their job that much easier. Certainly, simplification of design and also of designed parts makes for easier and faster machining in the finish mill. It's easier to sand and machine a simple rectangular dresser top than it is to do the similar operation on one that has a serpentine front and a shaped edge. Therefore, I think that production men should become perhaps the greatest exponents of a crusade for simplified design.

What would such a trend do to our present day machinery? Well, for one thing, it decreases the number of special purpose machines. If there were a great simplification all over the country, there wouldn't be as much need for turning out sanders or machines of that type.

*Presented at meeting of the Forest Products Research Society, Great Lakes Section, April 18, 1951, Grand Rapids, Michigan.

SOME SUGGESTED INNOVATIONS

Now with this thought in mind, I have asked myself the question what might be done on machines for preparing wood for finishing? Some of these ideas are old ideas and some of them have been tried many times. To my mind the principle of the drum sander is pretty wonderful. All you have to do is to adjust it and then stand there and feed it. The drum sander does the rest. However, in our present day thinking, when we run something through the drum sander we don't run it through with the idea of having it come out perfect. We always think that we will have to do some belt sanding. Therefore I don't think that the drum sander goes far enough. We can of course do solid work on the drum sander. We can do roughing and some polishing. We tried once to do all our polishing on the drum sander, that was one reason we had it rebuilt. We tried and had about 25 to 30 percent rejects. We couldn't find that much veneer to keep us going, so we quit. It may be possible to figure this out and I think a lot of work has already been done on it. Isn't there some sort of an automatic pressure adjusting mechanism that could be put on these drums so that they would rise when the material is warped and ride along with the warpage? I think the drum sander manufacturers have forgotten that wood does warp. Another thing that might be done is to put a separate set of rollers on the machine to hold down the warped pieces to the bed. At any rate I think it is most important that the drum sander manufacturers do some work on redesigning the machines so that we can do all kinds of sanding on flat work on them. At this rate the drum sander ought to put the belt sander out of business. On the other hand many belt sander manufacturers ought to be able to put the drum sander manufacturer out of business. If he believes that the belt sander is the only way to sand, then I should think that he might try to combine the features of the two machines. The belt sander does a fine job of sanding while the drum sander has this wonderful endless bed that feeds things right through. Is there a possibility that the endless bed could be worked out with the belt sander? I understand that some work is being done on this and I think that is a must. With such an attachment more of us might get into a two-machine operation, where we feed right through the belt sander on the endless bed to the conveyor between the two machines to do the polishing operation on the second machine. If we wanted to sponge we could even do it on the conveyor -- dry the material by infra-red heat.

How about some work on a sanding machine which could fit on the end of a moulder? We might work out a sanding head the same shape as the knives and in the same position and thus it would be possible to sand the material as it came through. Think of the operations that would save! Also, some of the manufacturers of the double-end tenoner - I wonder how many have tried putting small air drums on the double-end tenoner and sanding pieces running on the drive mechanism past these air drums. We manufacture a moulded plywood chair on which we apply the finish at the same time that we mould the part of the chair. Remember these face veneers have to be sanded, and they have to be sanded before moulding. So we finish sanding the 1/28-inch face veneer all by itself. We started out doing that by hand but the production was awfully low. With electric sanders such as the Sterling sander we didn't get a very smooth job. We decided that belt sanding was the best way. Oh brother, here was this buckly, floppy veneer on the beds and every time you touched it with the belt you would go right through it. We did fool around for quite a while and finally by a combination of the right paper and the right belt speed we were able to do this. We are sanding a large amount of 1/28-inch birch, ash, and walnut.

Some time ago we also tested sandblasting as a method of eliminating sanding. We haven't done much with it yet but I think it offers possibilities. I feel that sometime in the future it might be possible to do some of our sanding in a sand blast tunnel which would eliminate some of the hand sanding operations.

In conclusion, what should our objectives be for improving the machining of wood prior to finishing? I feel, as I mentioned before, that simplification of design and design parts is a must because we can then produce more and better parts with less labor. We try to convince our sales department to let our designs run longer, to hold designs in production longer. I don't see any reason why designs shouldn't run for 5 to 6 years. If we could do that, we would then build up special machines. Think of the use we could make of them! We could make furniture almost like they make automobiles. I hope not exactly like them -- mine's in the garage most of the time. If we could do that, we could afford to set up the machinery. Now we can't do it.

The machinery manufacturers should also continue to try to improve planing, moulding, shaping and routing and veneer cutting operation with a view to eliminating more and more sanding. It would be wonderful if some day machines could be so accurate and do such good work that we could forget about sanding entirely.

Quality Drying for Production *

E. M. CONWAY, Lumber Drying Specialty Company

THE WORD "production" for us holds a slightly different meaning than for most of you. At our plant our production is the output of our kilns. At Lumber Drying Specialty Company we do custom kiln drying, exclusively.

Since the output of our kilns is our bread and butter, you could be excused for thinking that "quality drying" is, with us, in second place to output. Some of you may possibly suspect that speed in drying, fast turnover and maximum production is far-and-away more critical in assuring that bread and butter than is the matter of quality. But, believe me, when you are paid for the drying job in dollars and cents and by the thousand, the type and quality of the drying job you do is much more important than how fast you do it.

The subject of quality versus speed, then, is more serious and important with the custom operator than with any other operator. We must do quality work, first, but of course we must do it with reasonable speed in order to stay in business.

We have nine dry kilns, both Moore and Standard. Their capacity is about 25,000 board feet each, with one holding about 50,000.

Let me outline first, some of our methods and practices for insuring top-quality kiln drying:

(1) We take plenty of samples. We believe that you can't do a good quality job of drying unless you know what's going on in the kiln, and that you can't know without samples. You cannot have good control over your kiln charge without good control samples. We make moisture tests when the lumber is stickered, again after the stock has passed the fiber saturation point (if green lumber is being dried) and again for our final tests. In between, we use the "calculated oven-dry" method, where the entire sample board is weighed. Occasionally and under some conditions, we may use an electric moisture meter. We select our sample boards carefully from the heaviest boards for their size as they are being handled in piling. We try to take at least one sample per thousand feet from smaller lots, and one for about 1,500 feet in car lots. More samples than this are used if the stock is both partly green and partly dry.

(2) We are fussy about our stacking and stickering. We know this pays off in definitely flatter, straighter lumber with less cupping, bowing and twisting. In fact, the only control anyone has over these defects normally is in careful piling.

(3) We used the new FPL schedules and use them carefully. Actually, we have been using schedules like these for several years, before the Forest Products Laboratory published them. I say we use them carefully, meaning that on stock that could possibly be damaged in the kiln we stay a stage or two behind their recommendations to allow for drying of the boards that are possibly wetter than our samples.

(4) We don't entirely depend on our kiln control instruments when drying the more refractory woods from the green. On ticklish drying jobs, being dried at low temperatures, we go inside the kiln and check the conditions with hydrometers. We keep our instruments calibrated, but remember, they operate by vapor pressure in the bulbs, and are least accurate at temperatures below 120° F.

(5) We condition the stock carefully for stress relief; under certain circumstances we precede the conditioning with an equalization treatment. Unless we are certain that the lumber is not going to be re-sawed, planed more on one side than the other, or routed out in such a way as to upset the balance of stresses. Unless we are certain that none of these things is going to happen to the lumber later (and we seldom can be) we must condition the stock carefully.

As far as speed is concerned, our average drying times for a few kinds and thicknesses of lumber are shown in Table 1

But after all, in any consideration of quality drying for production or quality vs. speed, there is amightyimportant element to be brought in--costs. We may be unique in this field of kiln drying in knowing almost exactly what it costs us to dry a species of lumber of a certain thickness at a given initial moisture content. We know our costs because kiln drying is our sole business. Furniture factories, lumber yards, and

*Presented at meeting of the Forest Products Research Society, Great Lakes Section, April 18, 1951, Grand Rapids, Michigan.

mills, have important costs such as administration, indirect labor, fuel, electricity and other overhead items too thoroughly mixed up with other operations for diagnose as to cost of kiln drying a thousand feet of lumber with any accuracy. Certainly it can't, in most firms, be done without complicated figuring which, as far as I know, is rarely even attempted.

If you operate fan type kilns on full time schedule (24 hours) and if they are not often idle, and if you will figure company overhead and other items and allow for replacement of the equipment, chances are that you can use this rule-of-thumb; figure $1.10 per M feet per day in the kiln, plus direct labor and supervision. If your steam is exhaust, 24 hours, and would otherwise be lost, this $1.10 should then become about 88 cents; if you burn shavings exclusively, it will likely be around 99 cents or $1.00.

TABLE 1.

HARDWOOD DRYING TIME IN DAYS

THICKNESS	4/4			5/4			6/4			8/4		
	Air-Dried	30-40%	Green	Air-Dried	30-40%	Green	Air-Dried	30-40%	Green	Air-Dried	30-40 %	Green
Basswood	3	5	6	4	6	7	5	8	10	7		13
Soft Maple	4	6	8	5	8	10	7	11	13	8		18
Willow	4	6	8	8	5	10	6	10	12	8		16
Aspen	4	5	7	5	7	9	6	9	11	7		15
Cherry	5	9	11	7	10	13	9	15	18	11		24
Sap Gum	4	6	8	5	8	10	7	12	14	9		20
Elm	5	8	10	5	9	11	8	12	15	10		22
Beech	5	9	12	7	11	14	9	15	13	11		27
Ash	5	8	10	6	10	13	8	13	16	10		23
Oak	6	15	23	8	20	27	11	28	36	14		45
Hard Maple	5	8	11	6	12	15	8	16	20	12		23
Birch	5	9	11	7	12	15	9	16	20	14		25
Mahogany	5	8	10	6	10	13	8	14	19	12		24
Walnut	6	14	19	8	17	22	11	23	30	14		40

Part Time Drying *

CLARENCE WOLFE, John Widdicomb Co., Grand Rapids, Michigan

WHEN OPERATING KILNS only during the work week (off over the weekend and nights) increased drying can be obtained during the shut-down periods by allowing the temperature to rise as high as it will during the last four or five hours on Fridays. At the same time, the wet bulb setting should be raised to give the same wet bulb depression as in the regular schedule for comparable dry bulb temperatures.

The effect of this last minute jump in temperature on drying can be illustrated with a few actual examples:

Twelve-quarter mahogany was dried at 134° F. The temperature was raised to 155° F. Friday P.M. for several hours before steam was shut off for the weekend. From Thursday to Friday loss in moisture content equalled 2.65 percent while from Friday to Monday moisture content loss amount to 6.1 percent. The following Friday the temperature was raised to 175° F. and the stock lost 8.2 percent (from 29.8 to 21.6).

Four-quarter cherry lost 6.9 percent over the weekend, with the temperature on Friday rising to 177° F.

DEVELOPMENT OF PART TIME SCHEDULES

This work was done in three Moore converted kilns with a capacity of 25,000 bd. ft. The species dried in these kilns were 4/4 through 8/4 birch, hard and soft maple, elm and walnut and 4/4 through 10/4 mahogany. The moisture content of this lumber ranged from well air-dried to 58 percent.

The kilns were operated on exhaust steam and only during working hours for 5-1/2 days a week, or a total of 55 hours a week. Fans were started when the steam came on in the morning and reversed at noon.

At first the procedure was to set dry bulb 10 to 15 percent higher than called for in the regular full-time schedule, while the wet bulb was set to give a corresponding wet bulb depression.

Gradually higher and higher temperatures were used until eventually it was customary to set the dry bulb 25° or more above schedule, advancing the wet bulb a few degrees higher than the required depression at that temperature.

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Representative part time schedule
10/4 walnut heart flitch

(Temperatures given are top temperatures reached during stated time)

Moisture content		Hours	Temperature	
From	To		Dry bulb	Wet bulb
35	30.7	10	135	132
30.7	28.3	20	135	129
28.3	23.5	35	135	127
23.5	20.5	20	150	123
20.5	13	35	180	141
13	8.5	40	180	128
8.5	3.1	80	190	128

Total: From 35 percent to 3.1 percent in 250 operating hours, or 35 days in kiln.

5/4 Elm

Moisture content		Hours	Temperature F.°	
From	To		Dry	Wet
51.7	44	6	174	158
44	19.4	15	179	159
19.4	14.1	10	180	155
14.1	11.2	10	183	144
11.2	8.5	20	180	142
8.5	3.02	35	180	132

Total: From 51.7 percent to 3.02 percent in 96 hours of operation, 13 days in kiln.

Comparative drying rates (in days)
For drying from 30 percent to 5 percent moisture content

	Mahogany (mostly quarter-sawn)		Soft and hard maple, elm, and birch	
	Part time Schedule	Full time Schedule	Part time Schedule	Full time Schedule
4/4	10	6	7	6
5/4	13	8.5	9	7.75
6/4	15	13	14	8.66
8/4	19	14.5	17	13.5

Estimated savings in coal and electricity in operating three kilns on a part time basis amounted to $4,800 a year.

Moisture distribution tests made on 8/4 Cuban Mahogany dried on a part time schedule gave the following values:

Average moisture content of whole samples, 5.55 percent (range 5.09 percent to 6.12 percent); average moisture content of core 5.45 percent; average moisture content of shell 5.66 percent. Greatest difference in 40 samples between core and shell 0.95 percent.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

A New Development in Wood Finishing*

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AMERWOOD

THIS PRODUCT is made from and remains real wood. It is not a synthetic, printed or embossed pulp product; all natural characteristics of grain, knots and growth are enhanced and developed. Almost any species of solid plank or plywood can be made into Amerwood. However, pine and Douglas fir have been used more to date because of their favorable price, abundance, and inherent characteristics.

Lumber for Amerwood is selected from the lower grades, not only because of the price but also more defects such as knots, checks, pitch pockets, etc., which produce a more beautiful finished product, are found in the number 2 and 3 common grades. This does not mean all lumber found in these grades is used in the manufacture of Amerwood. The lumber is selected from these grades but must be under 10 percent in moisture content, flat and straight, and free of sap stain, because when used as wall paneling it enters the class of interior trim. Coarse-grained, quick growth, lumber such as the field or loblolly variety with abundant knots is most desirable. However, each species including the splintery, dense jack pine found abundantly in the northern United States and Canada has its own characteristics and beauty when transformed by our process.

The first step in processing the board to produce Amerwood is to abrade it by means of the wheelabrator. This unit is a high speed bladed wheel 2-1/2 inches wide and 20 inches in diameter, driven through V belts by a twenty-horsepower motor. The wheelabrator utilizes centrifugal force, instead of compressed air, for projecting metal abrasive at high velocity and in a controlled direction upon the wood to be processed. This method uses no air, and is much cheaper and free from the hazards of compressed air.

The cast alloy impeller rotates with the wheel and carries the abrasive to an opening in the stationary control cage where it discharges to the bladed section of the wheel. At this point the abrasive is picked up by the inner ends of the throwing blades, and is gradually accelerated in its passage to the periphery of the wheel. The final throwing velocity is the result of radial and tangential forces. This means the blast utilizes all of the power supplied to the wheelabrator, which cannot be done with air. Change in direction of the abrasive blast is obtained by turning the control cage, which changes the position of the opening.

Four of these units are mounted in the top of heavy metal cabinets so as to blast down at the boards which are being carried through the cabinet by a heavy rubber belt four feet wide.

From four to five hundred pounds of metal abrasive per minute is thrown from each against the surface of the board. The metal abrasive is varied in size according to species of wood, an average is forty-mesh in size. Production can be varied by increasing the size of the cabinet and number of wheels. This blasting removes a portion of the soft springwood forming deep recesses between the exposed hard summer growths.

The metal abrasive mixed with wood fibres is collected in a large hopper under the cabinet from where it is elevated then screened to separate wood from metal. The broken down fine particles of metal are also removed allowing the larger pieces of abrasive to deposit in the storage hopper above the wheels for re-cycling.

The speed of the belt through the cabinet can be varied from ten to thirty feet per minute. For pine it is usually operated at fifteen feet per minute. At this speed a soft textured pine board can be processed in one pass. Boards of harder and tougher texture require more passes. An average of two to three passes does the job. The four-foot machine with four units easily produces 1, 500 surface feet per hour.

From the wheelabrator cabinet the blasted board now passes through a series of wire brushes, at a rate of forty feet per minute. This operation removes loose fibres and smooths the surface both in the recesses of the spring growth as well as the hard ridges of summerwood, adding greatly to the desired smooth touch.

*Presented at meeting of the Forest Products Research Society, Great Lakes Section, April 18, 1951, Grand Rapids, Michigan.

[1]The wood finishing processes described in this paper are covered by U. S. patents and the equipment and procedures are licensed by the holder of the patents. The processes are described here because of the unique methods and equipment employed.

By conveyor this board now enters a second wheelabrator cabinet. Here color is applied in dry pigment state at a low angle across the board so as to high light the high ridges of summer growth and not touch the low recesses of spring growth. The material projected from the unit, revolving from a horizontal position on a vertical shaft at 1,000 rpm., consists of a mixture of vehicle and dry pigment color. The vehicle or carrying agent which can be either metal, sand, aluminum oxide or many other types of materials is mulled with the pigment so as to load the interstices of the vehicle. The muller being a part of this machine is located under the reclaiming hopper, where vehicle (carrying agent) and pigment meet. The muller consists of a traveling rubber belt having multiple stationary rubber wipers which cause the small granular vehicle to roll over many hundreds of times in the pigment which it picks up. The mixture is then elevated to the storage hopper where it is re-cycled by gravity through a selected orifice into the wheel. Approximately twenty pounds of this mixture is fed per minute.

The pigment is fed into the reclaiming hopper under the machine by means of an electric vibrator. This can be very accurately controlled by a mere twist of the knob so as to keep the color standard perfect at all times.

Now that the board has been blasted, sanded, and colored, it is passed again by mechanized conveyor into the spray booth where automatic spray guns apply a protective coating of heavy bodied lacquer.

The board continues on its way through the continuous infra red oven. A flashing out period of three minutes is allowed on the conveyor before reaching the heat. For five minutes the board is subjected to 150° F.

For five minutes after leaving the oven the board is cooled before passing into the final operation of waxing. This machine consists of a rubber belt conveyor which carries the board at forty feet per minute under a series of revolving brushes. The first is a wire brush at 900 rpm. to remove bristles and raised grain caused by lacquer and heat. The second brush revolving at 120 rpm. is a wax applicator. The solventless, cake wax is placed in a metal box having sides only. At the bottom it gradually melts away on the hot metal roll heated by infra red bulbs. The wax applicator brush, located below the hot metal roll picks up the wax and deposits it on the moving board. The two successive tampico brushes revolving at 900 rpm., produce a final smooth touch to Amerwood.

It is now ready for packaging and shipping. Its primary uses are wall paneling, furniture and novelties.

AMERSTAIN

Throughout the woodworking industry, and particularly in the furniture division, more thought is being devoted today to the finishing department than other phase of the business.

The slogan: "Design and finish sell the product" is certainly as old as the industry itself; but in spite of this known fact, manufacturers have always made the greater portions of their capital investments in the mill room. It is not uncommon even today for the plant manager to replace a fairly modern woodworking machine, such as moulder or double end tenoner, with a more modern tool at a cost of $15,000, or $20,000 in order to reduce the time of an operation from eight minutes to six minutes per hundred pieces; while up in the finishing room nothing is being done to reduce the time of an operation from eight minutes per piece to two or three minutes, which is entirely possible.

Some manufacturers have installed expensive conveyors and automatic spray guns, but these are few and far between. They have not proven versatile enough to meet the demands of the furniture buyer. This equipment has not reduced the hand wiping of stains and fillers nor the toning and blending required for uniformity and beauty. These operations are identical with those of fifty and even one hundred years ago, and unfortunately too many buyers still buy on a cost per gallon basis rather than a cost per finished product.

The Amerstain method developed by our company is one of the major outstanding improvements in the wood finishing industry for many years. No liquids are used. Dry pigments, the same as used in liquid pigment wiping stains, are mixed with a vehicle or carrier such as fine sand, metal grit, nut shells, synthetic granules or many other types of materials. The proportion of mixture is approximately two hundred parts of carrier or vehicle by weight to one of pigment. This varies according to the carrier used and the depth of color desired. This mixture is then blasted or projected by means of centrifugal force, compressed air, or low pressure blower on the surface of the wood. The blasting takes place inside a well ventilated cabinet similar to a spray booth either by automatic and mechanized means or by hand similar to the spray gun. Millions of particles of pigment are deposited on the wood surface by the carrier in a matter of seconds. Any pigment not deposited on the wood is reclaimed in a matter of seconds. Any pigment not deposited on the wood is reclaimed and recycled back with the carrier in the same exact proportions as desired. The amount of pigment actually consumed is therefore astoundingly small. Hard textured panels receive exactly

the same amount of pigment as the softer ones; this produces uniformity. The article is then removed and, without any drying time, is immediately sprayed in sealer, generally of the lacquer type. The solvents disperse the pigments and draw them deeply into the pores and interstices. Some critics have questioned the depth of color penetration by this method, but tests have conclusively proven many times that lacquer type solvents penetrate far deeper than oil type pigment wiping stains.

Oak can be glued up in a solid panel along side of soft maple and produce a uniform beautiful red maple finish by the process described.

The equipment required resembles a spray booth. It can be adapted in size or shape to take any piece of furniture or wood product. The article is placed on a turntable and revolved as the operator blasts wherever desired with a flexible, light hose. This equipment is very versatile and the operation is similar to the conventional method of spraying. However, where sizes are uniform and high production is required, automatic equipment is available. The article is merely hung on a hook which passes through the blast and on to the finishing spray booth. Any desired rate of production is possible.

In summarizing comparative costs of Amerstain with conventional liquid wiping stains, both materials and labor are considerably less. Since no drying time is required, the finishing schedule is much faster and there are no drying ovens or tunnels, and, of course, less finishing room space is required. This method produces a beautiful finish at lightning speed and at extremely low comparative costs.

AMERGRAIN

The afore described process is carried a step further to produce an amazing finish known as AMERGRAIN. By this method the natural grain, of discolored, sap stained, and mineral streaked wood, is produced in any desirable color without bleaching.

Instead of blasting directly on the wood as is done in the previously described process, an opaque coat, generally white, is first applied by the usual method of spraying to completely obliterate all discoloration. This white undercoat is a very thin, rough, high-hiding, and low-solid-content material. After drying, the surface is blasted in exactly the same manner as described in the Amerstain method. Pigments and carrier are mixed in any selected proportion to give the desired tone of color by a mere turn of the knob on the electric control.

The wood grain and figure is reproduced in all its various designs and textures on top of the white coat in much the same manner as the youngster in school reproduces the image of the buffalo nickel by placing a sheet of paper over the coin and rubbing it with his pencil. By bold relief the buffalo is reproduced, by modified relief and variation in texture the wood grain is reproduced in any desired color including blond, wheat, or the light pastels. Clear coatings such as sealer, lacquer, and varnish are then applied in the usual manner. Durability has not been helped nor hindered by this process, durability of course depends on the quality of the top coats.

Today, sap streaks and mineral stains are far more prevalent in both plywood and solid stock than ten years ago, but the demand for light finishes has steadily grown stronger year by year. Almost every furniture manufacturer today is confronted with the problem of producing light finishes on dark woods. The demand today has reached over fifty percent for light finishes. Ours is the one simple, speedy and inexpensive process which meets this demand. As compared to bleaching and similar practices it is far cheaper, much faster and more satisfactory.

An entirely new field is opening in wood finishing. Never before has it been possible to produce colors such as blue, green,pink, yellow, etc., except in solid opaque enamels, wherein the grain and wood characteristics are lost. But by the new process any and all of these beautiful colors can be produced over black streaked or sap stained woods without losing the inherent values and beauty of endearing qualities.

The intriguing factor about this process is that the wood figure is reproduced faithfully. The hard summer growth is dark and the spring growth is light whereas with liquid stains the opposite takes place since the stain strikes into the soft portions and not into the hard.

Natural Wood Finishes for Exteriors of Houses*

F. L. BROWNE, Chemist, Forest Products Laboratory, Forest Service, Madison, Wisconsin.

INTRODUCTION

NATURAL FINISHES for wood siding on the exteriors of houses have become increasingly popular during the past 15 years. Woods that have a rich brown or red color of their own, such as redwood and western redcedar, lend themselves particularly well to natural finish, though woods of paler color, such as cypress, pine, knotty pine, and Douglas-fir are sometimes finished in that way. Those who have learned to use suitable materials for a natural finish and to apply and maintain them correctly have usually found them pleasing and satisfactory. On the other hand, some who have tried natural finishes without first learning what they require have been disappointed and have changed back to the older practice of hiding the wood under a coating of house paint.

PROBLEMS OF NATURAL FINISH MAINTENANCE

The first thing to learn about natural finishes is that they are much less durable and therefore must be renewed much more frequently than coatings of house paint. House paint should go at least 4 years before needing renewal but natural finishes nearly always need renewal at least once a year. On parts of a house that are fully exposed to sunshine and rain natural finish usually needs renewal every 6 months until it has been done three or four times, after which the intervals may be somewhat longer, though seldom more than 12 months. On more sheltered parts of the house yearly renewal may suffice and in deep shade the intervals may be even longer.

As a rule the lowest courses of siding on the south side of the house are most severely exposed and need most frequent renewal of natural finish whereas the highest courses of siding and the overhang under the eaves of the north side are the most sheltered and can go longest between renewals. Trees or neighboring houses, however, may shift the locations of greatest and least exposure to other parts of the house.

Need for renewal of finish becomes evident when the luster or glossiness originally imparted to the wood by the finish fades to the dullness of unfinished wood. Another test is to splash water on the surface to see whether the water rolls off quickly in droplets or spreads on the wood and is soon absorbed. In the latter case freshapplicationof finish is in order. Needed renewal of finish must not be delayed too long. For if it is postponed unduly, the wood begins to acquire a gray color that turns still darker gray when more finishing eventually is done. To restore the desired color after serious grayness has developed, the surface must be scraped or sandpapered until the wood is bright again. If the wood is allowed to become roughened and cupped as well as grayed by weathering, the restoration of a smooth, bright surface becomes very laborious. For that reason the timely renewal of natural finish simply cannot be neglected. Similar neglect of coatings of house paint is less serious.

There is no way of keeping wood very long with exactly the color and nearly complete absence of gloss with which it comes from the lumber yard. A finish that could do so would enjoy a good market. But any protective finish that can be applied necessarily penetrates slightly into the wood, displaces air from wood cells, and seems to deepen the color of the wood even if the protective material has no color of its own. Moreover, by filling the pores in the wood, the protective material makes the surface smoother and therefore imparts at least a moderate degree of luster or glossiness. As time passes there is further change of color because sunlight gradually darkens the color of most woods by changing yellows and reds toward brown. Even the weakened sunlight that gets through windows eventually darkens interior woodwork. If in addition the protective finish itself darkens with age, as most of them do, still more change in color must be expected. Fortunately aged wood is still more attractive than freshly cut wood.

Natural finishes may be divided into three broad types, the oil finishes, the wood sealer finishes, and the varnish finishes. They differ in the composition of the material used, in the appropriate methods of application, in the resulting appearance, and in important characteristics of performance. The paint industry, however, has no such generally recognized classification of finishes; the trade names of commercial products do not necessarily indicate the type to which they belong. Thus a material may be

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sold as a "log cabin oil" and yet turn out to be either a sealer or a varnish. The user must judge from such information about the composition as may be given on the label and particularly from the way the product behaves when he starts to apply it.

OIL FINISH

The natural finish with the lowest degree of luster or gloss is the oil finish. It also darkens the color of the wood more than other natural finishes do because the oil penetrates farther into wood. Moreover, the oils are inclined to continue darkening with age more than most sealers or varnishes do. The darkening, however, can be largely corrected by incorporating a little pigment in the oil as is described farther on.

The simplest and oldest oil finish is ordinary linseed oil, either raw linseed oil or boiled linseed oil. Unless the work can be done in warm, dry weather it is best to use boiled oil or else to add about one-sixth of a pint of liquid paint drier to a gallon of raw oil. Most painters also like to add some volatile thinner to linseed oil, thinking that it makes the oil penetrate deeper. That is not the case but thinning the oil helps to avoid leaving any excess oil on the surface. Turpentine, mineral spirits, or other thinner sold for mixing with paint may be used but do not add more than a half gallon of thinner to a gallon of oil.

The oil may be applied by brushing, spraying, or mopping. For new wood two good coats are needed. But it is most important to see that all of the oil sinks into the surface of the wood. If, after the second coat has been applied and has stood 20 to 30 minutes, there are any glossy places where excess oil stands on the surface, it should be wiped off before it has time to harden. Coatings of linseed oil are unsatisfactory not only because they are too glossy but because they are inclined to run or to wrinkle when they dry. In any event coatings of oil are too soft, tend to hold dirt, and become mildewed easily. In renewing the oil finish after it shows signs of wear one fresh application should suffice. Again, any excess not drawn into the wood should be wiped off. (Do not forget that oily rags are a fire hazard. Burn them promptly or keep them in a tightly closed metal container until they can be burned.)

Trade-brand products may be purchased at paint stores. They are often called log oils or log cabin oils because the natural finishes for exterior woodwork first became popular for summer cottages built of peeled logs. The commercial products are usually made of bodied linseed oil, tung oil, or other drying oils and thinners. Bodied oils have been heated or treated chemically to increase the viscosity greatly, after which a greater proportion of inexpensive thinner must be added to restore suitable viscosity for application. The bodied-oil finishes do not penetrate so deeply into wood as raw or boiled oil does and therefore do not darken the color of the wood so much. The product approaches the properties of a wood sealer more and more closely as the degree of bodying is increased.

The trade-brand oils should be applied and maintained just as has been described for the raw linseed oil finish. Since a bodied oil is more apt to leave an excess standing on the surface than raw oil is, special care should be taken to wipe off the excess before it becomes hardened.

The oil finishes give their best service in dry places where there never are any prolonged periods of dampness, such as southern Arizona. Where dampness may linger for some time the oils are subject to attack by molds, the fungi that grow on surfaces. On finishes the condition is usually called mildew. A dark, almost black discoloration may result. Mildew can be prevented by incorporating suitable preservatives in the oil finish. Some, though by no means all of the trade-brand oil finishes already contain preservatives. If so, the kind and amount should be stated on the label. Mere statement that the product itself is a preservative, however, is meaningless because the paint industry's use of that word may have no such significance.

If linseed oil or a commercial product not containing preservative is used, there are two ways of incorporating suitable preservative. One way is to buy one of the concentrated solutions of pentachlorophenol or other chlorinated phenols sold at lumber yards for preserving wood and to mix it with the linseed oil instead of adding turpentine or paint thinner. If the directions on the preservative say that it is to be mixed with three times its volume of fuel oil for use as a wood preservative, it may be mixed one volume of concentrated preservative to three volumes of linseed oil for a linseed oil finish. The other way of accomplishing the purpose is to buy one of the water-repellent preservatives now sold at many lumber yards and some paint stores and apply it to the wood before the linseed oil finish is put on. In the second case most renewals of the finish can be done with the linseed oil alone, for the treatment with water-repellent preservative need not be repeated for 3 or 4 years.

The oil finishes may be further modified to advantage by incorporating a small amount of pigment in them. Usually a pigment of reddish-brown color is desired to simulate the color of

the heartwood of redwood or redcedar. The pale color of any sapwood present in the lumber is thereby changed to resemble the heartwood more closely and such woods as pine or Douglas-fir are given a richer color. Moreover, better maintenance of color is achieved because the presence of the pigment tends to mask the gradual darkening in the color of the wood itself. If renewal of finish should be delayed until some boards become slightly grayed from weathering, the pigment helps to restore the desired color, provided the graying has not been allowed to go too far. Finally, presence of a little pigment usually adds appreciably to the durability of the finish. Of course, the amount of pigment must be small, well short of the point at which it would give a painted or even a stained appearance.

A number of the trade-brand oil finishes on the market contain pigments. Such products, of course, should be stirred thoroughly before use and should be stirred from time to time during use. Linseed oil or prepared oils without pigment can be pigmented just before use by adding a small proportion of burnt sienna ground in oil, which is sold at paint stores for tinting paints. The sienna-in-oil should first be stirred thoroughly with a little of the oil until it has the consistency of a thin paint and is free from lumps. It can then be stirred smoothly into the rest of the oil. About 1/2 pint of sienna-in-oil to a gallon of oil may be right but the exact proportions are best determined by trial by adding the color in small amounts at a time and applying the mixture to sample cuttings of the wood to be finished until the desired appearance is obtained.

Unusual natural finishes can be made in similar fashion by adding colors other than the reddish browns. Thus attractive finishes for redwood, redcedar, cypress, or knotty pine are sometimes made by adding just a little white, cream, or pale gray paint.

WOOD SEALER FINISH

Like the oil finish, the wood sealer finish is a penetrating finish that should not be permitted to build up on the surface into a glossy coating. Sealers do not penetrate wood so deeply as oils do. For that reason the sealers usually darken the wood less and give the surface more luster or glossiness than the oils do. The sealers, however, are less glossy than varnish finishes unless too much sealer is applied and the excess is not wiped off.

In composition, wood sealers are much like varnishes except that the sealers contain more thinner and less nonvolatile matter. Both are made as a rule by cooking resin and drying oil together in suitable proportions, incorporating driers, and thinning to proper consistency. Many kinds of resin, both natural and synthetic, may be used. The difference between a sealer and a varnish lies more in the method of application than in the composition. Wood sealer finish, like the oil finish, sinks into and saturates the wood surface without forming a continuous coating of appreciable thickness over it, as varnish finish does.

There are many wood sealer finishes sold at paint stores under trade-brand names. Unfortunately, the names and the directions given for use often fail to indicate clearly whether they are intended to be wood sealers or varnishes. In particular, the necessity of wiping off any excess material not absorbed by the surface is seldom properly emphasized in the directions. The uninformed user therefore may start out with a sealer finish and end up, after one or two renewals, with a varnish finish. On the other hand, those who wish to do so may buy a good spar varnish or marine spar varnish and obtain a sealer finish by using the varnish appropriately. Simply thin the varnish with about an equal volume of turpentine or other paint thinner and apply and maintain it as described for the oil finish.

Although most wood sealers are more resistant to mildew than the oils are, sealer finishes are more readily attacked by fungi than are good house paints. Wherever there may be lingering dampness it is advisable to have a preservative in the sealer finish. Some of the commercial products already contain preservative. Otherwise preservative may be incorporated in a sealer finish by either of the two methods suggested for oil finishes.

Some commercial wood sealers contain pigments for the same desirable purposes already described for oil finishes. The user may also add pigments to sealers lacking them by following the methods suggested for pigmenting oil finishes.

VARNISH FINISH

Unlike either oil finish or sealer finish, varnish makes a highly glossy coating of appreciable thickness covering the wood. Varnish may not darken the color of the wood to begin with much more than a sealer does but with the passage of time there may be more darkening caused by change in the varnish itself than would be the case with a wood sealer. It has long been customary to varnish front doors and other relatively small areas of exterior woodwork but the high gloss of varnish is seldom what is wanted for natural finish on large areas such as the siding of a house.

Nearly every paint store sells spar varnish of one trade brand or another. Marine spar varnish, intended for use on boats, is apt to be somewhat more durable than ordinary spar varnish. Varnish is applied by brushing or spraying. At least three coats are needed for new wood but for renewal one coat at a time is sufficient. On new wood the first coat may be thinned moderately with turpentine or other paint thinner. Shellac must not be used for the first coat on exterior surfaces even over the knots in knotty pine. The succeeding coats are expected to stand out without penetrating the wood and, of course, none of the varnish is wiped off.

When renewing varnish finish it is difficult if not impossible to limit recoating to the more exposed portions of a sidewall where renewal is needed. The freshly applied varnish does not match in gloss and color the older varnish. Thus the protected areas must often be recoated even though they do not need renewal.

Where there is dampness at times finishes need preservatives against mildew much like sealer finishes. Unless the varnish already contains a preservative it is advisable to apply a water-repellent preservative to the wood before starting to put on varnish. It is seldom practicable to add a concentrated preservative to a varnish because varnish cannot well stand much addition of thinner. Similarly it is not good practice to add pigments to varnish. If pigmentation is desired, it is best to apply a pigment oil stain to the wood first and then to varnish over it.

On the whole, experience with varnish finish on large areas of exterior woodwork such as siding has not proved satisfactory. Often the varnish finish develops milky, opaque patches where the coating has lost its adhesion to the wood without breaking open. Some varnishes craze or crack in an unsightly manner after which renewal of the finish is difficult. After two or three renewals the coating becomes too thick and begins to crack and scale badly. It then becomes necessary to removal all of the old varnish with varnish remover before the finish can be properly restored. Such removal is expensive and laborious.

FINISHING HARDWOODS

The methods of natural finishing described so far are suitable for all of the softwoods and for hardwoods with pores no larger than those in birch. Hardwoods with pores larger than those in birch, however, usually need special treatment for the pores after water- repellent preservative, if used, has been applied but before oil, sealer, or varnish is put on. The treatment for pores consists in application of a paste wood filler. "Natural" wood filler is a transparent material that does not alter the appearance of the pores. Colored wood fillers are also available that accentuate the pores, usually by making them dark brown or black, and thereby emphasize the grain pattern of the wood.

To apply paste wood filler, thin it with paint thinner to a consistency suitable for brushing and then apply it like paint, but brushing across the grain of the wood rather than with the grain. Then let the coating stand a few minutes until the initial wet, glossy appearance changes to a dull aspect. Next wipe off the excess filler with clean rags, burlap, cotton waste, or other suitable wiping material. Wipe first across the grain to pack the pasty filler into the wood pores, then finally wipe lightly along the grain to avoid leaving slight streaks of excess filler crossing the wood grain. When the filler has dried -- at least overnight -- the finish coats of oil, sealer, or varnish may be applied.

For varnish finishes on hardwoods with large pores use of wood filler is necessary to avoid danger of premature failure of the finish. For wood sealer finishes the use of filler is strongly recommended, though it may not be essential. For oil finishes filler may be omitted if so desired.

DOORS AND WINDOWS

Doors and windows usually need more careful maintenance of protective finish than is necessary on siding. Retention of smooth surfaces, snug joints, and accurate shape and dimensions are essential for good appearances and proper functioning of doors and windows. Paneled doors have a number of joints that readily collect and retain rain water to the detriment of the wood unless protection by coatings is well maintained. Paint or trim enamel affords the most reliable means of keeping up the needed protection. For that reason careful consideration should be given to the choice of paint or trim enamel for the exterior surfaces of doors and windows even when natural finish is selected for the siding. Paint of a color matching that of the naturally finished siding may be used if desired.

But if natural finish is insisted upon for doors or windows it is probably best to apply a full varnish finish consisting of three or four coats because varnish gives better protection against wood weathering than oil or sealer finishes do. The varnish must, of course, be renewed as often as proves necessary and when the coating becomes too thick to avoid cracking, alligatoring, or bad scaling it must be stripped off with varnish remover before revarnishing. Such removal is less burdensome and expensive on the limited

areas of doors and windows than it is on a large expanse of siding.

Varnish may last longer on doors and windows than it does on siding because the doors and windows, except their casings, are set back into the sidewalls, receive more protection from roof overhang than the lower courses of siding, may be sheltered by porch or entry roofs, and often are covered by storm sash or doors or fly screens for considerable portions of the year.

Windows and doors made of pine or other wood containing sapwood may well be treated with water-repellent preservative before they are installed. Such treatment helps to prevent blue stain in sapwood, which causes discoloration even through paint coatings, and also affords some protection against decay at vulnerable points.

RUST STAINS

Woods that contain tannins, such as redwood, redcedar, oak, and chestnut, readily produce a black color when brought in contact with iron rust and a little moisture. Soluble compounds of iron react with tannin to form a blue-black compound related to some writing inks. Other extractives present in many woods may also form strongly colored compounds with iron. Exterior woodwork, therefore, should always be fastened in place with corrosion-resistant nails, screws, or other fastenings if it is to receive a natural finish. Such fastenings, in fact, are well worth while even when the wood is to be painted. Similarly hardware to be fastened to the exterior surfaces of wood should be resistant to corrosion, for the rain water dripping from rusty iron or even copper or brass can discolor wood and even paint. Well galvanized iron, cadmium-plated iron, aluminum, zinc, and stainless steel do not discolor wood. Corrosion-inhibitive paints will keep iron or steel hardware from discoloring wood, provided the protective coating is maintained adequately

Clear finishing materials to be applied to wood must also be free from soluble compounds of iron. Shellac varnish or other spirit varnishes that have been kept in rusty metal containers or have otherwise come in contact with iron rust will blacken woods that contain tannin or other extractives that react with iron. Even oil-soluble water-repellent preservatives, oil finishes, and sealer finishes have been known to produce black specks on redwood or oak woodwork when the material was applied from rusty paint pails. Similarly exterior woodwork that has been smoothed with steel wool may develop black specks after the first rain from particles of steel left in the surface of the wood.

CHANGING FROM NATURAL TO PAINT FINISH

It is not a good plan to start out with natural finish on a new house as an experiment with the idea of changing to paint finish later if the natural finish fails to please. It is much better to visit houses that have been kept in natural and in paint finishes for a few years to learn what experience teaches and then to choose finally before the house is completed. For reliable painting the first or priming coat applied on the bare wood is more important than any coat that can be applied subsequently. The priming paint for a paint job should be one designed specifically for that purpose. None of the natural finishes complies with the requirements of a good priming for paint coatings.

If however, there are good reasons for painting a house that has previously had a natural finish, the change can be made reasonably satisfactorily, provided suitable precautions are taken. If the natural finish was of the varnish type or a sealer that has been allowed to accumulate until it becomes essentially a coating, the wood surfaces should first be stripped of all clear material with varnish remover. Any wax the remover left behind should then be washed off with paint thinner or with soap and water. Next, light sandpapering of the surfaces is usually advisable. Painting can then be done just as on a new house. Removal of all clear finishing material is most necessary on the protected areas of the house, even though the natural finish may remain in best condition there.

If the natural finish was of the oil type or of the sealer type and remains strictly within the wood surface, it may be practicable to apply paint without first removing the clear material. In that case, however, it is wise to let at least a year elapse after the last coat of clear material was put on before attempting to apply paint. If after that time some of the protected areas remain more or less glossy, the surface should be sandpapered until the glossy material has been removed. The first coat of paint applied should then be a priming paint suitable for use under the paint chosen for finish coats and applied just as it would be on new wood.

Natural finishes for major areas of house exteriors are a relatively new development with which many painters have as yet had only limited experience. This report has therefore dealt at some length with the various misunderstandings and difficulties that have come up in the Forest Products Laboratory's consultations with house owners, architects, builders, painters, and others. But when the requirements and limitations of the natural finishes are properly

considered in advance and the necessary precautions have been taken, owners of houses have found them practicable and have been well pleased with them.

Varnish finish scaling from gable end of house in southern Arizona. The house was only 3 to 4 years old, but the varnish had already been renewed twice.

Varnish finish turning white from loss of adhesion and starting to scale. The house, in Wisconsin, was only 1 1/2 years old and had been revarnished once. (Red cedar siding)

Sealer type finish giving good service on a house about 15 years old in Wisconsin. The finish on the redwood siding originally consisted of one application of water-repellent preservative and one of wood sealer. For several years an application of sealer was made twice a year but more recently the finish goes a year or slightly more before needing renewal.

Materials Handling *

JERRY SCHUETTE, Thomas Ingerman Company

IN THE PAST TEN YEARS modern material handling methods have developed all down the line, from forest to finished product. Greatest lumber demands fell on sources of greatest available supply: Hence, the West led in the mechanical handling revolution. The South saw, appraised, then followed. The North then realized that it had to modernize or die as an industry. Developments have been rapid in recent years, and all of you are now more conscious of material handling costs than ever before.

Old methods and tried and true designs were accepted out of habit as the best. Improved methods and machinery were expensive. When demand for lumber products was high, and business good, the industry could afford old costly methods, with the excuse that there was little time to plan a modernization program. When demand fell off, and business slumped, such a program was too costly to consider.

Some had the foresight, the courage, and the means to act. Equipment and processing machine manufacturers were improving designs right along, but the market for their products was sorely limited for many years.

I mentioned a modernization program. Some operators invested in one or more of the modern machines, but didn't avail themselves of the full advantages such installation offered, because there was no integrated program. Processes before and after the new unit were not geared to it.

Electric hoists, low lift trucks, high-lift fork trucks for yard and plant use, conveyors, and load-levelizing lifts are accepted methods in the metal, ceramics, and paper industries, but they are only now finding their proper place in the lumber field. Once you have experienced the advantages such equipment offers, you're quick to develop the system. A general survey of industry states that material handling costs account for thirty to thirty-five percent of product cost. Materials handling adds nothing to value, only to cost. I believe the thirty to thirty-five percent figure is conservative for your industry.

Unit-load handling of lumber in yard, storage, and kiln drying is a recent advancement. Conveyors and lifts are designated as part of, or accessories to, some modern processing machinery. If the same principles involved in these improvements were studied, analyzed, and applied to other operations in your plants, the benefits could be extended materially.

Old handling methods cause congestion in plants, and when new methods are considered, this congestion is cited as the reason modern methods can't be used. Many plants have developed like "Topsy," they just growed and growed! In growing, the flow of materials and the placement of processing machinery developed without the efficiency straight line production offers. Revising current flow lines now is a costly thing to consider. Ultimately, it would pay off, but in many cases, an expert analysis and survey of present conditions would pay off by your taking fullest advantage of what might be done under these conditions. Cost of re-arrangement might seem high, but might be well worth the investment.

Proper materials handling practices will reduce costs through manpower saving, increased storage capacity in existing space, greater safety for the men and reduced damage and waste.

Cut stock, semi-processed, can often be handled on pallets or skids, stored high in racks, or sometimes without racks, by using high-lift fork trucks. Handling and storage of volume materials, can be improved at lower cost through methods proved in other industries with similar products. You may be able to save floor space for storage, handling costs into and out of storage, improve control of rotation of materials subject to deterioration, and probably reduce purchase costs by buying in larger units.

In your industry pre-machine operations take you back into the timber. The modern power saws, crawler cranes, diesel cats, power winches, and other modern mechanical equipment have multiplied man-hour production. In 1942 lumber consumption in the United States was 43.4 billion board feet. The previous high consumption year was 1925 with 40 billion board feet. It is estimated that less than two-thirds

*Presented at meeting of the Forest Products Research Society, Midwest Section, September 19-21, 1951, Oshkosh, Wisconsin.

as many man-hours produced the larger figure: This is attributable to improve methods.

Log handling, from source to saws has seen remarkable advances in recent years. The very nature of the log appears to limit any major advances over current modern methods. From the pond or cookers, onto the bull chain, and through the saws, you seem to use, or are aware of, latest equipment. The size of the operation determines the type and speed of saws used.

The high speed saw carriage has pointedly changed production figures. It is the pace-maker in plants which have subsequent operations, geared accordingly, through the use of improved methods and equipment.

Some of you receive lumber, not logs. The costly and tedious job of handling it from the car to yard stacks, kilns, storage or production is often accepted as a necessary evil. Gondola or flat car shipment hasn't proven satisfactory, so the box car or closed truck is the accepted shipping method. A power conveyor for carrying the lumber from the car or truck to stack has recently been introduced. Grading and tallying can be done at the receiving end of the conveyor. Lumber is then carried to one or more piles. Unit loads are arranged for handling with high-lift fork truck.

Full or semi-automatic equipment is available for feeding lumber from unit loads into and through the processing machines.

The through-the-machine phase of modern material handling has been adequately taken care of by your woodworking machinery builders. They offer safe high-speed machinery complete with power feed, discharge, and travel to next process. Where a conveyor is not used for pieces in process from one operation to another, four-wheel, platform, push-type, or some type of mechanical-lift truck and skids is called for. Surplus runs, not needed for immediate production are piled on trucks, skids or pallets, then transported to storage for future use. Here the use of pallets or skids, a high-lift truck and storage racks eliminates the old method of hand unloading, hand piling into storage, and hand-reloading of truck when these parts are to be placed in production. Unit loading and storage eliminates three hand operations necessary by the old method. Note the slow and fast moving inventory items, and the related problems and solutions.

Large panels, frames, and doors present a handling problem. A hand or power-lift truck with a long lifting bed frame, used under a long skid platform, has proven to be the best solution. Proper piling of these long pieces on the skid can improve safety and efficiency. Reducing load overhang beyond the rear axle of the truck as pile height increases offers greater load stability, easier rolling, and lower truck maintenance.

I recommend the use of racks for multiple-tier storage of loose or unstable loads. Flat boards, cases, crates, boxes, kegs and drums can be tiered on pallets with no need for racks.

All industry is modernizing through mechanization. In many cases equipment has been offered and purchased without proper planning. Installation of a new unit has often been made on a basis similar to replacing one spark plug in a car instead of replacing the whole set, having a general tune up, and deriving full benefit therefrom.

Modern equipment, too, demands a new conception of maintenance. This must, also, be systematized. Many benefits can be derived by a planned maintenance program to care for older types of handling equipment. Use and care of proper types and sizes of trucks, wheels and casters is important, if you wish to do the best with what you have. Waiting for the wheel to squeak before applying grease is a costly policy.

Many firms have appointed a man or committee from among their qualified employees, and assigned to them the project of surveying present operations. Their findings are analyzed by management, as, also, are their recommendations on improvements. A materials handling department is then established, and is hence forth responsible for that phase of the plant's operations. A standard maintenance policy is set up, tied in with this department. Department heads cooperate, as do the men under them. This cooperation includes suggestions on better methods, greater safety, and needs for repairs on replacement.

The size of your operation dictates the extent to which you can go, but the basic principal involved pays off, even in comparatively small plants.

Industrial engineering firms specialize in surveys. Manufacturers of lumber processing machinery and materials handling equipment, including conveyors, have men qualified and willing to help you save money. Proper equipment, properly used, is not an expense: It's an investment, and usually pays greater dividends than you expect.

Modern Methods of Handling Lumber *

W. L. IRWIN, Assistant Works Manager, Poinsett Lumber and Manufacturing Company, Pickens, South Carolina

THIS PAPER is concerned with the methods, procedures, and equipment involved in the handling of lumber at the Pickens Works of the Poinsett Lumber and Manufacturing Company.

When designing the Pickens layout, all other forms of lumber handling including the lumber carrier type were studied. The method adopted involved the use of the best equipment and ideas we could find or devise, keeping in mind that we wanted to retain permanent foundations, railroad trackage, transfer cars, kiln cars, and other equipment we already had.

The equipment involved in this handling includes the lumber slip, kiln cars, transfer cars, stacking unit, crane unit, diesel locomotive, railroad trackage, and lumber foundations.

Lumber comes from three sources, the sawmill slip, freight shipments, and truck shipments.

SORTING

Our method of handling lumber at the slip in general is to separate the species, the lengths, the thicknesses, and the grades as much as practical. Some species are run in such small quantities as to make it impractical to separate them into any of these groupings. Other species are partially separated, especially as to length, that is, lengths are combined. The lumber is pulled by hand from the slip chains and flat stacked on the kiln cars at the proper slip position.

LOADING KILN CARS

When a kiln car is loaded up to about 2,500 feet, it is pulled from the slip by the electric transfer car and an empty is set into that position. This load of lumber is then placed on the track leading to the stacker (see Fig. 1). When lumber is received by freight, somewhat the same procedure of separation is followed and the boards are flat stacked by hand directly onto the kiln cars, since the kiln cars are on adjacent tracks.

When lumber is received by truck our sawmill 25-ton crane is used to unload the lumber, by a sling arrangement, onto the kiln cars. All cars for stacking are transferred by our small diesel locomotive or the electric transfer car to the track leading to the lumber stacker.

THE STACKING OPERATION

At the lumber stacker a crew of five people perform the stacking operations. The stacking unit consists of three separate units, the tilt lift, the accumulating conveyor section, and the straight or vertical lift.

A load of lumber first comes to the tilt lift operator who winches it by means of an electric winch onto the tilt lift. Hydraulic power tilts and hoists the lumber to unloading position. The tilt lift is raised a layer at a time to permit the operator to start the boards down the incline where they fall onto the accumulating section (see Fig. 2). As the boards progress along the accumulating section, the ends are automatically brought into line by a bumper arrangement. When enough boards are accumulated to build one layer, the accumulating section operator trips a switch. This switch sets up an automatic cycle which activates arms coming up to separate the lumber at the proper width and other arms moving this layer forward, depositing it on the load on the vertical lift, and returning to the start position.

Lumber stacking sticks 1 inch by 1-1/2 inches by 76 inches are used to separate the layers of lumber while 4-inch by 4-inch by 80 inches unit stacking sticks are used to separate the unit packages of lumber.

Three men are used to lay the sticks. A layer of lumber is placed in approximately 15 seconds. The middle man in the stick laying crew lowers the vertical lift the thickness of the boards to provide for the laying of the next layer.

To lay the unit sticks the rear stick guide tilts back permitting placing of the unit sticks.

When a kiln car is loaded up with units of stacked lumber the stacker rear stick guides tilt, and the accumulating section moves out of position, to enable the load to be raised by the hydraulic track to await the transfer car.

When stacking for the kilns, lumber is stacked to the correct height on stacking sticks and unit sticks are left out.

*Presented at meeting of the Forest Products Research Society, Virginia-Carolinas Section, October 26, 1951, Clemson, South Carolina.

When stacking for the yard, units are built up with stacking sticks, and beneath each unit 4-inch by 4-inch unit sticks are placed on 4-foot centers for the purpose of handling the unit.

Because our lumber yard crane is limited in the size unit it can handle, we have had to limit 14-foot and 16-foot lumber to a unit size such that four units comprise a kiln car load. On 12-foot and shorter lumber, three units comprise a kiln car load. Stacking sticks are placed in all stacking on 2-foot centers.

Production at the stacker is 10 to 15 M feet per hour depending on length of lumber and whether or not lengths are mixed. Purchased lumber is usually mixed and it does not pay to separate all the lengths so it is stacked in mixed lengths. This procedure slows down the stacker as the boards are rick racked.

Each unit is scaled and recorded on card as it comes from the stacker. This card is the record for all subsequent lumber yard operations.

YARD MOVEMENTS

The kiln cars of lumber coming from the stacker are transferred to the alleys handling that species by the electric transfer car. When several kiln cars have been placed on the alley track, the yard crane will transfer to that track and will get behind the group of cars, hook up to them and push them down the alley to the lumber foundations. The crane is a locomotive type and pushes the loads until it reaches the pile bottom where it will unstack the first car, unit by unit (see Fig. 3). The empty car is then picked up and set behind the crane, and the crane proceeds with the rest of the cars to the second pile bottom.

As each kiln car is unloaded of units the empty is set behind the crane and, therefore, the crane unstacks all the cars before returning to the stacker.

The opposite of this procedure is performed if lumber is picked up at the lumber foundations and stacked on kiln cars for the kilns. All operations of loading and unloading of lumber on the lumber foundations and the transferring of kiln cars to and from the lumber yard are performed by the operator and helper on the crane unit.

ADVANTAGES AND DISADVANTAGES OF THE PICKENS SYSTEM

The advantages of the Pickens system are as follows:

1. The help required to handle this large amount of lumber is small. Approximately 20 men were cut off our yard when this system was installed.

2. Weather is no factor in the system as the stacking is done in buildings and the helper on the crane and helper on transfer car are the only men required to work out in the elements whether the weather is good or bad. Previous to this system we were always faced with layoffs when weather turned bad.

3. The yard is kept much neater and more uniform. Odd piles and partial piles are eliminated. No stacking sticks or boards are scattered around the yard.

4. This system permits permanent lumber foundations (see Fig. 4) which everybody recognizes as being superior to any temporary or wood foundations. Lumber is supported at all points required for good practice and held straight.

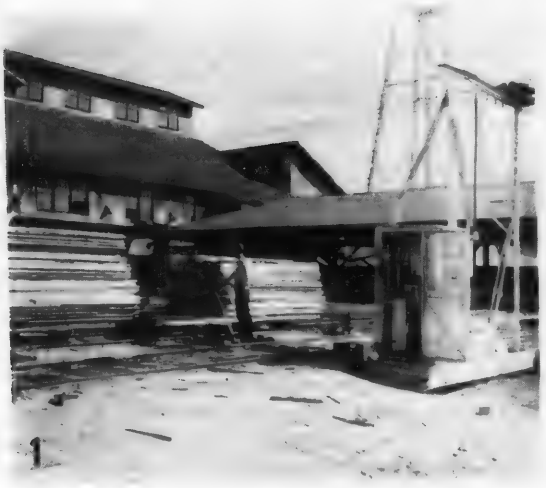
5. Air circulation is of the best, as the lumber foundations are designed with ample ground clearance.

6. There is very little maintenance in this system. The equipment is all sturdy and large. Tracks are the greatest maintenance problem. We have ballasted ours to keep down grass and weeds as well as for proper drainage.

The disadvantages of the Pickens system are:

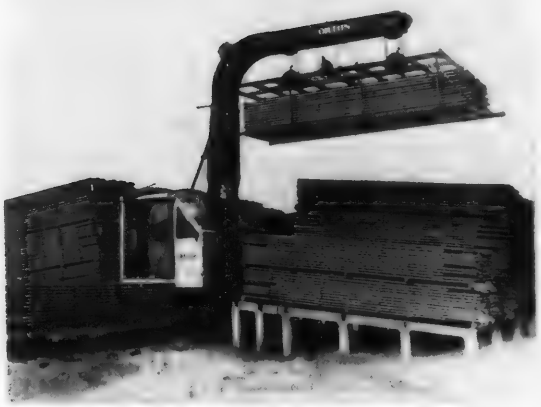
1. The initial investment in such an arrangement is high, mostly because of the permanent foundations, the trackage, and the steel kiln cars required.

2. The stacking unit and yard arrangements are necessarily a high production unit. It, therefore, requires that ample lumber be available or other work be available for the men so that operations do not drag.

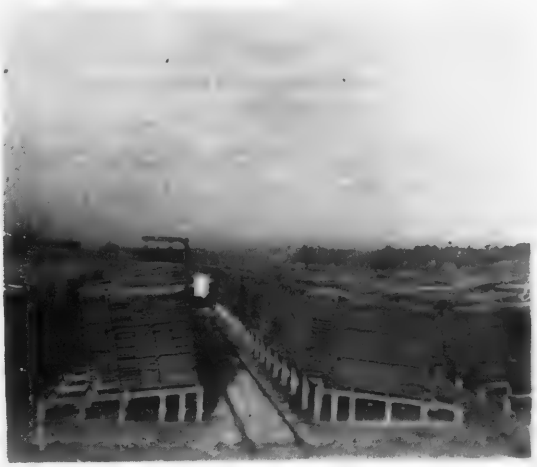


Modern lumber yard with locomotive crane handling unit packages on steel and concrete foundations.

Automatic stacker with five man crew. Unit stacking sticks at left foreground and lumber stacking sticks at right foreground.



Crane unit stacking unit of lumber on yard.



End view of unit of lumber in crane cradle. Note clearance between adjacent stacks.

Transferring of kiln car of lumber from sawmill slip to stacker track by transfer car.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Proper Method of Loading Lumber *

C. E. SIMONSON, Loading Supervisor, Trans-Continental Freight Bureau, Seattle, Washington

THE PROPER METHOD of loading lumber and plywood on railroad cars has always presented a problem and the railroads are constantly trying to get the shipper to load correctly so as to get the shipment to its destination with the least amount of delay. Rules have been formulated to make safe loads with the least expense to the shipper.

In the shipping of lumber there are several things to take into consideration in making the load safe and keeping it intact to its destination, including impacts received in yard handling, coupling slack in the train, and the oscillations of the load in transit. Having these things to contend with, we realize no rule can be made to keep the load from end shifting on the car, but we know that we can keep the load intact in normal handling if certain rules are followed. The loads at all times must be made compact and no vacant space be left between the material in the unit or pile. If lumber is of such dimension that it does not fill the entire width of the car, suitable vertical filler stakes must be applied to take up the vacant space and secured with a "T" block at the top of the filler.

In the preface of the loading rule pamphlets issued by the Association of American Railroads are these words which every shipper should keep in mind when loading railroad equipment, "The protection of human life and property should be borne in mind." I am sure if everyone concerned with loading would bear this in mind, a great many of the accidents that have occurred would not have happened. Being a member of the "On the Ground Forest Product Committee" which works under the direction of the Association of American Railroads Forest Product Committee, what can and does happen when cars are improperly loaded is brought home to me very vividly.

The Association of American Railroads has formulated a set of twenty-one general rules for the loading of open top cars and I think that everyone connected with the loading of cars should acquaint themselves with these rules so they would have a fair knowledge of the specifications for good and safe loading. I am going to quote some of these rules, all of which are based on many years of exacting study and experiments.

Rule 2 provides for hand brake wheel clearance of at least six inches between the outside edge of the brake wheel and the load. A minimum of twelve inches clearance from the end sill of the car to the load will give the necessary six inch brake wheel clearance required by law. If this clearance is not maintained the carrier is subject to a heavy fine for the violation, if caught by the Interstate Commerce Commission's inspector. This also holds true for any safety appliance that is damaged, such as hand holds, sillsteps, etc., that may be damaged by the shipper's trucks or carriers that happen to come in contact with them.

Rule 3 concerns all loading of open top cars regardless of the commodity. There must be sufficient clearance between the side bearings to permit free movement of the trucks. This means that it is necessary to have a balanced load by having the weight evenly distributed crosswise of the car. If the load should happen to be heavier on the one side than the other this would cause a binding of the bearing on that side and would not allow free movement of the trucks going around a curve. This could cause the car to derail and result in a serious accident. This has happened many times and just recently caused the wrecking of thirteen cars on one of the southern railroads.

Rules 4 and 5 govern weight limitations and the equal distribution of the weight on the car and also the location of the load on the car. Every railroad car has a stenciled load limit on it. This load limit is figured so that the axles under that specific car are not overloaded and should carry the load without a breakdown.

Rule 7 is very important, as it has to do with railroad line clearances. The height and width of the load must be within the clearance limits of the railroads over which it must move to its destination. It is up to every person in the transportation end of the lumber industry to see that the clearance limits of the railroads are not exceeded.

The last general rule that I want to quote is Rule 10, which is also very important. It gives

*Presented the Forest Products Research Society, Pacific Northwest Section, March 12, 1952, at Seattle, Washington.

the specification on the size of car stakes, their quality, the specification for the cross tie across the top of the load and the number of stakes required for the different lengths of material being loaded. I want to stress that particular attention should be given to the stakes and that they must be straight grained and free from strength impairing knots. Also in the cross tying of the stakes after the car is loaded good sound lumber be used for the crossties. This rule also states what type of lumber can be used in the making of the stakes. They must be made of the following unless otherwise specified: sound hardwood, longleaf yellow pine, spruce, or fir.

Previous to 1943 the railroads were experiencing considerable trouble with dressed lumber on open top cars. The rules at that time were not as specific as those we have today. In going over some of the old rule books dating back to 1917 I could not find any mention made about having the loads packed solid as the rules of today require. It was up to the individual railroad originating the load as to whatever extra blocking they felt was required. Many of the roads set up their own regulations making it confusing to the shipper as to what was required to ship over the various lines. As long as the load met with the minimum requirements of the loading rule book the connecting roads had to accept it. In one instance at one ot the interchange points in June of 1943 there were over 2,000 loads on their repair tracks for the adjusting or reloading of poor loads. In the majority of cases it was the short material in the inside part of the load that cored itself out because it was not loaded compactly. The presence of short material and failure to pack the load solid have been the main things to contend with as short material will work out and cause the load to become loose and disarranged in transit because of oscillations set up by the motion of the train. In trying to eliminate this hazard the rules required at one time that where there was more than one pile of lumber on the car, a four-inch riser must be placed under the outside ends of the piles to tilt them toward the center of the car. This did not work out satisfactorily as it acted as roller when the car was handled in yard switching, and in train movement it acted as a creeper for the lumber to work itself right off the end of the car because of oscillations. They they tried placing a bulkhead on each end of the load to stop the loss of material from the cars, but that did not do the job intended as the bulkheads often broke down from the end shifting of the load.

With the cooperation of the West Coast Lumbermen's Association and the wire and band companies, the Association of American Railroads conducted four tests of one hundred cars each of dressed lumber, since that was the material they were having the most trouble with. One hundred cars were loaded using high tension wire or high tension bands in two locations encircling the top third or half of the pile depending upon the location of the pile separators. Another hundred cars were secured in the same manner with two additional bands or wire encircling the entire pile. The third test conducted was with the use of black annealed wire applied in the same manner as in the two previous tests. This black annealed wire was cable twisted before application to give it more strength. The fourth test was without the use of any wires or bands. All these test loads were completely loaded under careful supervision so that the tests could be properly made. These loads were shipped to various parts of the country so they would be subjected to various handling conditions. The wire and band fastenings proved very successful and were incorporated in the present rules.

I am going to give you the present rule which has worked out very satisfactorily:

Stakes - On piles 12 feet to 24 feet long inclusive - three pairs. Add one pair for every additional 10 feet in length.

Under the specific figures on loading you are given the kind of stakes that can be used and in the lumber figure they have added that southern pine, larch and hemlock that can be used as stakes.

Cross Ties - Two 1-inch by 4-inch in one piece long enough to be sawed off flush with the outside face of each stake. The substitution for this is the use of a 3/4 inch by .035 high tension band or a No. 8 gage high tension wire looped around the two opposite stakes and machine-secured in the center.

Separators - Piles 12 to 24 feet long inclusive - three. Piles 24 feet long to 40 feet long - four. Piles over 40 feet long - five. Length of the separator must be equal to the width of the load but must not extend beyond inside face of stakes. They must be two inches wider than their height and cannot exceed four inches in height. Place directly behind the stakes or as close as possible. Make one separation, located about midway on loads 4 feet to 8 feet high. Add one for each additional 4 feet in height, spaced as equally as possible from the car floor. Floor bearing pieces when used must be placed in the same manner as the separators.

Longitudinal ties - 1 inch by 4- inch, long enough to extend four inches beyond stakes nearest to the end of pile. Secure with three 8d nails to each stake directly above or below the cross ties. Ends of the ties must overlap each other

not less than two feet and each joint must be secured by five 8d nails clinched on the back. In gondola cars an additional longitudinal tie must be applied at the top of the car sides. When a bottom tie cannot be placed between car and stake and extend at least one inch below the top of a gondola car side, nail it to outside of car stakes as near to the top of the car as possible with three 8d nails. The rules provide details for reinforcing the connection between tie and stake.

The tying up of the upper portion of the load is required on all rough and surfaced lumber except the following:

Loads 4 feet high or less.

Rough Lumber over one inch in thickness, but required for two inch material, four inches or less in width.

Finished lumber over four inches in thickness and eight inches in width.

Lumber over 24 feet in length.

When high tension bands are used for tying the upper portion of the load, no less than 1-1/4-inch by .035-gage band can be used or less than No. 8 gage high tension wire applied in two locations on each pile.

Two end-for-end piles must be as close together as possible to prevent shifting.

When lumber of unequal lengths 12 feet to 24 feet long is loaded in the same pile, longer lengths must not overhang the shorter lengths by more than a total of four feet.

Load lumber less than 12 feet long on flat cars, or above gondola car sides as follows:

No lengths less than 12 feet to be loaded on outside of any pile.

Lengths ranging downward to 8 feet minimum may be loaded on the inside of end piles provided lumber in uniform lengths less than 12 feet must not be loaded within 24 inches of the top of pile. Random lengths of lumber under 4 inches in thickness, lapped and interwoven, including 6, 8, and 10 feet lengths must have six layers on top with lengths less than 12 feet in these layers.

If the rules that I quoted are followed closely I am sure we would have much less trouble with lumber loaded on open top cars.

It has been noted that in shipments of plywood when damage is reported it generally occurs to the corners and edges of the plywood sheets. This damage is caused by the rubbing of sheets in adjacent stacks and against the car ends and sides. The finished surfaces of the plywood sheets also are damaged when allowed to slide or move about on one another. In order to overcome this the Association of American Railroads has recommended that plywood should be loaded and protected in the following manner:

Plywood should be loaded flat, in stacks lengthwise or crosswise of the car with vertical strips of scrap plywood or other suitable material placed between adjoining ends or edges of stacks.

To prevent movement of the lading crosswise of the car, bracing must be applied between the various stacks in the car and the side wall of the car.

Vertical movement of the lading and overshifting of sheets is controlled by the use of hold downs. Hold downs may be constructed entirely of wooden members, pocket cleated to the car side walls or by using wooden members held in place with steel strapping. When steel strapping or high tension wire is employed as a hold down or the unitizing of each lift of plywood, it must not come in contact with the plywood so it is necessary to place scrap plywood between the band or wire and the sheets of plywood.

The top sheet of each stack of plywood should be covered with a heavy kraft paper to prevent damage to the finished surfaces of the plywood. This sheet should be folded under so the lower sheet will hold the paper in position.

One thing to remember in loading any commodity in closed cars is the application of side door protection so the commodity will be kept from contacting the side doors of the car. If this is not done there is a possible chance of lading shifting crosswise of the car in the doorway and putting a pressure on the door so that it might be forced off the car and cause a serious accident or possible fatal injury to someone. This happened with a closed car here in the Northwest going to the East Coast. The commodity broke loose in the car and shifted against the side doors causing the door to be forced off the door rail. The door fell on a car inspector in the train yard and killed him.

I want to impress on you that it is vitally necessary to apply side door protection where there is a possibility of the commodity coming in contact with the side door.

Producing Hardwood Dimension Stock *

FERD J. HAAS, M. B. Farrin Lumber Company, Cincinnati, Ohio

INTRODUCTION

IN THE PRESENT UNCERTAINTY it becomes increasingly difficult to plan for the future. What will happen to costs, both material and labor? Will volume increase and present problems of production, or perhaps decrease and leave gaps which we try desperately to fill? Or will it remain normal? What is normal?

Large manufacturing plants, such as industrials, furniture and cabinet shops, in most cases are equipped with facilities which permit them to start with the raw material and work up to the finished product. Perhaps by arranging to purchase certain parts in a semi- or completely finished state, they may provide for better cost control, increased production and higher returns. At the same time, inventory problems are simplified, important factory space may be used to better advantage, and fluctuations in volume are taken in stride.

The development of quality production of kiln dried hardwood dimension has gone far toward simplifying the many problems faced by manufacturers of numerous items requiring prefabricated hardwood parts. It was not an easy task. Mistakes were frequent and costly, but the patience and perserverance of both producer and consumer eventually resulted in a practical understanding of mutual problems. The benefits have been far reaching in the lumber industry as well, stimulating the demand from new sources and at the same time making it possible to supply a greater quantity of parts without unnecessary waste of raw material.

OBJECTIVES OF HARDWOOD DIMENSION PRODUCTION

It is quite obvious that there are two major considerations which must be met if success is to be achieved in the dimension field, as near as possible, complete satisfaction to the customer, and a fair profit return to the producer on the goods manufactured. With the proper coordination between the mill and estimating department, acoomplishment of these two important goals can be reached. We shall assume that the cost system is functioning properly and try to analyze the proper production methods from an economy as well as quality standpoint.

Speaking in generalities, we are attempting to take a specific amount of rough kiln-dried lumber, and by a skillful use of our facilities, produce a predetermined amount of finished product which will please our customer. The selection of the grade of rough lumber to be used for the particular end product is highly important. We must determine from the sizes and grade to be produced, the most economical grade of lumber we can use both from the standpoint of labor as well as yield. The line of least resistance is to take the highest grade available, which, in turn will most certainly give the best yield as well as use the least labor, but one other item must be considered -- the cost to the mill of that particular grade, versus the cost of the next lower grade which will produce the end product with slightly additional labor and slightly less yield. It is in this particular situation that the manufacturing methods and efficiency of the labor in the plant are the determining factors in the assurance of a profitable operation.

In times past, and perhaps in some rare instances today, where, for example the spread in prices between FAS and No. 1 Com. was comparatively small, it was a definite advantage to use the higher grade. As a general rule, today, you will find that the price differential will, in most cases more than offset the slightly lower yield, and higher labor, and enable you to show a greater margin of profit. Concurrently with this thought, the investment is considerably lower and should there occur excessive kiln damage, (heaven forbid) this percentage of loss is relatively lower.

It would be unwise to attempt to determine a standard method of production which would be applicable to all types of products. What might be the most suitable for one operation producing a variety of items in various thickness and grades, might be cumbersome for a plant whose production is largely the same from month to month. We generally consider, however, a dimension plant to be set up to supply the needs of a variety of customers, so that it must be fairly flexible, and have trained personnel who can adapt their thinking to the particular requirement of an order, such as poplar or gum cores

*Presented at meeting of the Forest Products Research Society, Virginia-Carolinas Section, October 26, 1951, Clemson, South Carolina.

or sound panels at one time and perhaps clear two-face maple or oak finish the next time.

PRODUCTION PROCEDURES

Briefly, let us consider a more or less standard procedure. It should be the responsibility of the superintendent to see that the lumber being used is of the proper moisture content by making periodic checks with a moisture meter, or by oven test, so that he is sure he will encounter no difficulty with his finished product on account of excessive moisture or in some cases extreme dryness. As a general rule, there is sufficient leeway which provides a margin of safety, but one or two cases of spoiled merchandise will quickly justify this extra precaution in starting production.

For the great majority of orders upon entering the mill it is desirable to put the stock through a rough planing operation, setting the planer approximately 1/32 to 1/16 inch under the standard rough thickness. By so doing the operator of the cross-cut saw can more readily determine the location of defects, hence speeding this operation and later on when the stock is passed through the straight line rip, the resulting joint is square and perpendicular to the face, an important factor in securing a proper glue joint. In performing this surfacing operation, however, it is well to consider the condition of the lumber as to flatness. Inasmuch as it is possible to split boards which may have too much warp, the operator should lay these aside and later on send them to a rip saw to be ripped in the middle before surfacing.

After rough surfacing, and assuming the product involved may be solid or glued up, the lumber would then be cross cut to approximately one inch longer than finished length, regardless of the width of the pieces. Again, in this operation the waste factor is directly proportional to the skill of the operator, possibly at this point to have a decided effect on the amount of waste developing on the order.

The next operation is largely dependent on the character and grade of the cross cut material as well as the nature of the finished product. If the product is to be molded to a width of 6 or 7 inches or less it will be advantageous to send the stock directly to the straight line rip where the operator can rip a good portion of the stock solid width without gluing. The balance of the narrower pieces may then be sent to the glue clamp, glued in sheets of a multiple width and then reripped to the proper width. On the other hand -- if the product is of considerable width, necessitating all stock to be glued up, it is generally more profitable to have the pieces move through the continuous glue jointer, thereby putting the jointed edge on the piece with less waste of lumber than by ripping. To make this practical, however, stock must have fairly straight edges and be of fairly high grade.

If the operator should run in to a small percentage having too much side bend for the jointer, he can simple let these go in and the rip saw operator can handle these as they appear. Then too, should occasional pieces get through to the glue clamp with only one jointed or ripped edge, they can be assembled so that the unjointed edge of the piece is placed on the outer edge of the panel. In the case of core stock, for example, considerable responsibility falls on the rip operator. He must, first of all, be familiar with the type of panel to be produced from the core, whether the edges are to be concealed in the final use, or whether they may be shaped and be partially or completely exposed.

In the case of edges not showing, less care need be taken in assembling the pieces for gluing inasmuch as sound defects on or near the edge would not necessarily be detrimental. However, in case of the shaped exposed edges, he must watch carefully for a good percentage of clear narrow strips or strips with a 2- to 3-inch clear edge and always obtain enough so that the clamp operator has sufficient to make panels with clear edges and ends. In some cases where the lumber being used is of fairly low grade, a percentage of the next higher grade may be necessary to produce the clear-edge stock.

The ultimate grade of the core to be produced must be carefully checked and discussed with the customer so that no misunderstanding may exist and cause unnecessary trouble at a later date. Another mark of good workmanship is the careful re-drying of the glued panels before they reach the final stage of planing, so that the moisture of the glue in the joint may be thoroughly eliminated so as to prevent sunken joints upon application of the veneer. However, in the case of electronic gluing operations this hazard is eliminated as the moisture is expelled at the time of gluing.

VARIATIONS OF THE PROCESS

It will be noted that in the foregoing we have routed the lumber through the rough planer then cross cut, ripped and glued. Generally this will be found to be the most favorable procedure, although not an iron clad rule. There are many instances where it will be found more advantageous to rip the lumber lineal after rough surfacing and cut the blanks to length afterward. One example would be, of course, the production

of moldings where length is desirable, and where presumably the upper grades of lumber are to be used. Another example might be in the production of assorted lengths of the same finished width particularly where the customer will not permit gluing up of the piece. By ripping in the lineal length, the producer is able to salvage the narrower stock in long lengths for other use in nearly any length he may wish. Should the stock have been cross cut to a specific length, he would be limited in utilizing the narrow stock. Perhaps the second most important factor in a successful operation is the careful planning of utilization of waste, not only in careful cutting and ripping of natural defects, but obtaining waste in such manner that it may readily be used to produce certain orders which will be secured for material of narrower widths or shorter lengths than average. (The first important factor being, of course, economical production of quality merchandise.)

Other factors to be considered in quality production may include minimum handling by correct routing through machines, sharpness of equipment -- planer knives, saws, etc., small conveyors where practical, sufficient blow-pipe capacity, comfortable working temperatures, cleanliness in the glue room, preliminary inspections during course of operations, constant checks on quality of glue, i.e. frequent checks on different batches and perhaps numerous others which will all add up to pay off in dividends.

The proper production of kiln dried hardwood dimension is indeed a science. Aside from the progress made over a period of years and knowledge gained from experience, it must give credit to numerous other industries for its constant advancement -- manufacturers of dry kilns, handling equipment, machines, adhesives, high speed steel, etc. It is a tribute to the dimension mills to have obtained the confidence of so many civilian users of their product and we can be most thankful for the large part they played in the last war by furnishing innumerable high-priority wood parts efficiently and quickly. There are headaches, to be sure, but in the final analysis, the constant sincere efforts of a comparatively small group have succeeded in what might be termed the most exacting phase of our lumber industry.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Testing Wood Doors for Stability and Strength *

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INTRODUCTION

WOOD DOORS have always been in great demand. Part of this demand is due to the present high levels of construction activity in all fields. But this is not the only factor; despite the great variety of structural materials made available by engineering research, wood continued to be the favorite for making doors. In a 500-bed hospital recently built of steel and masonry for the Veterans Administration at Madison, Wis., a major item was 2,000 wood doors.

In response to the demand for wood doors, many new types are being made and marketed. Most of these are flush-type doors, in which relatively thin covers are glued to an edge frame and a core, either solid or hollow. Some flush-type doors have been in use long enough to afford knowledge of their service behavior; others are new and untried. There is need for standard performance tests and specifications by which the fitness of these new and untried types of doors can be judged.

Performance tests of doors have been made at the Forest Products Laboratory for more than 25 years. Early work was sponsored by the Wholesale Sash and Door Association to compare different ways of joining the parts of a conventional panel-type door. Work has continued more recently in cooperation with the National Housing Agency, the Housing and Home Finance Agency, and various manufacturers of wood doors. In 1948, the Housing and Home Finance Agency issued Technical Paper No. 10, "Properties of Four Experimental Flush-type Doors," based on research by the Forest Products Laboratory.

This research has both an immediate and an ultimate objective. The immediate objective has been to observe the performance characteristics of various types of doors and to compare one type with another. The ultimate objective is to develop performance-test methods and standards, so that the fitness of a new type of door may be judged without waiting for its record in service.

*Presented at meeting of the Forest Products Research Society, Midwest Section, September 19-21, 1951, Oshkosh, Wisconsin.

METHODS OF TESTING DOORS

Methods of test fall into three general groupings. There are stability tests, which are intended to show the stability in size or shape of a door when it is exposed to unfavorable conditions. Strength tests are designed to show the stiffness as well as the strength of the door, stiffness being probably the more important. Lastly, there are impact tests to show resistance of the door to rough treatment, one of the impact tests also gives some measure of the strength.

Exposure to Changing Moisture Conditions

Exposure to changing moisture conditions is primarily a test of stability in size, though the shape may also be affected. A wood door is usually so assembled that the grain of adjoining parts runs in different directions. Since wood shrinks and swells much more across than along the grain with changes of moisture content, such changes set up internal stresses. These stresses tend to cause warp or change of shape and may be sufficient to bring on mechanical failure. An increase in moisture content also results in an increase in the dimensions of the door.

This test is simple to perform. An unfinished door is preconditioned to a low moisture content, then brought to a high moisture content by exposure for a few weeks in a damp atmosphere, and finally dried to the original low moisture content. The test conditions used at the Forest Products Laboratory employ atmospheres at 80° F. and 30 percent relative humidity and at 80° F. and 80 percent relative humidity. These conditions result in a low moisture content of about 6 percent and a high moisture content of about 16 percent. Test observations include the increase in size under high moisture content, extent of return to the original size with subsequent drying, and visual inspection for warping or structural failure.

The moisture-change test has rather severe effects on interior doors. The increase in size is often enough to cause serious sticking of a well-fitted door, and minor structural damage (glue-line separation or checking of face veneers) is not uncommon. To be more nearly comparable to actual service conditions, a cycle for interior doors should possibly employ a change of moisture content of only about 6 percent rather than 10 percent, as in the present method.

Exposure to Differential Moisture Conditions

Exposure to differential moisture conditions is primarily a test for stability of shape. When a wood door is exposed to conditions that cause one side to be at a different moisture content than the other, the dimensions of the moist side become greater than those of the dry side, and the door becomes cupped with the dry side concave. In this test, an unfinished door is exposed to a controlled moisture differential, and its departure from the original plane is observed. The door is then allowed to recover for a certain period of time, after which the extent of its recovery is observed. About three weeks' time is required for the full amount of cupping to take place. The test is made on a door built into the wall of a cabinet, with the atmosphere inside the cabinet humidified and that on the outside dehumidified. Relative humidities are such as to lead to a moisture content of about 16 percent on the inner side and 6 percent on the outer side of the door. This reversal of the condition of exposure of an exterior door in service was for ease in setting up the test; it does not affect the results, as the doors tested are of the same construction on both sides.

Under such unbalanced conditions, the ordinary interior door becomes deflected or cupped from one-fourth to one-half inch from the original plane. When the moisture differential is removed, a well-made door recovers all or nearly all of its original shape. Structural damage in this test is rare. Observations of doors in service indicate that cupping in excess of one-fourth inch is generally considered to be cause for complaint. On the other hand, the test method may be too severe for interior doors, which are not usually exposed to a severe or protracted moisture differential.

Strength Tests

Since breakage of a door under static loading rarely occurs in service, the so-called strength tests are made primarily to furnish a comparative measure of stiffness. Two types of racking tests are made.

In the racking-parallel test, the door is hung in a vertical position, supported along one edge, and loaded on the other edge in a direction parallel to the plane of the door. (Fig. 1) Such a loading simulates the racking effect of the weight of the door or a vertical load applied to the door handle. In the racking-perpendicular test, the door is placed flat, supported at two diagonally opposite corners, and loaded on the other two corners in a direction perpendicular to the plane of the door (Fig. 2). This simulates the effect of horizontal forces applied in opening a door that is stuck at one or both ends. In actual service, loads of this type are considerably below the ultimate strength of most doors. The essential test data are observations of deformation under standard test loads, 500 pounds in the racking-parallel test and 200 pounds in the racking-perpendicular test.

Flush-type doors with well-glued faces have so much rigidity in the racking-parallel test that deformations under any realistic test load are so small as to be insignificant. Deformations in the racking-perpendicular test are greater and afford a good means for comparing stiffness of various types of door construction. Since results in both tests seem to be affected by the same characteristics in doors, the racking-parallel test could be omitted entirely and comparisons of stiffness based only on the racking-perpendicular test. In the latter test, deflections of various types of doors under a 200-pound standard test load range from one inch up to several inches.

Impact by Falling Ball

In this impact test a falling ball is used to measure resistance of the cover or surface of the door to indentation and breakage by a sudden blow. The door is placed in a horizontal position, and a 2-inch-diameter steel ball weighing a little over a pound is dropped on it from various heights (Fig. 3). Observations are made for depth of indentation or for breakage. Small square sections of wall panels have been tested by impact of the same steel ball, a method that is also directly applicable to wood doors.

This test is critical on hollow-core doors with thin facings and serves to place a lower limit on the resistance qualities of the cover. All drops cause indentation, and drops from a height of only two feet sometimes cause visible breakage. Since impacts of this kind may result from a wide variety of causes, it is hard to determine what should be a satistactory standard of performance. Where comparative depths of indentation are important, a test on a small, square section of the door is expected to give more consistent results than the test on the whole door.

Impact by Sandbag

Impact by a 10-pound sandbag has more extensive effects on the door than the impact of the two-inch-diameter steel ball. In this test, the door is supported in a vertical position and struck by a swinging leather bag that is five inches in diameter and filled with enough sand to weigh 10 pounds (Fig. 4). This method is also used in impact tests of wall panels. Impacts on a part of the door near a framing member or a supported edge are more critical than those at a place where the door can yield more freely. Damage occurs in the interior of flush-type doors or is visible on the reverse side before it appears on the side struck by the bag.

The sandbag-impact test can cause damage that may be quite varied in location and nature; it is a good test for revealing mechanical weakness or imperfections in manufacture. Ability to sustain repeated impacts from a 1-1/2-foot height has been proposed as a requirement for wall panels. Doors tested at the Forest Products Laboratory have shown first damage under blows from heights ranging from 3 to 10 feet.

PERFORMANCE OF DOORS TESTED

Testing to date has included about a dozen types of doors, the majority being flush types with glued covers. Several of the doors are shown in cross-section in Figs. 6, 7, and 8 in comparison with a conventional panel-type door (Fig. 5).

Most flush-type doors show fairly good stability of size under exposure to changing moisture conditions. While all doors increase in size as their moisture content is increased, there is generally a substantial return to the original size when the doors are again dried. Conventional panel-type doors with doweled joints increase more in width but about as much in length as do the flush-type doors. Minor structural damage in the form of checking of face veneers or slight separation of glue lines is quite common in doors with glued parts, whether panel or flush types. It is believed that a cyclic test of this kind is effective in showing up any imperfections in gluing.

Effects of exposure to differential moisture conditions have been similar in all the types of doors so far tested. In general, the doors depart one-fourth to one-half inch from their original plane, returning very nearly to that plane when the differential moisture condition is removed.

Flush-type doors with glued faces are noticeably stronger and stiffer than conventional panel-type doors in the racking-parallel and racking-perpendicular tests. Neither type suffers critical deformation under loads of the magnitude likely to be experienced in service.

Hollow-core doors with thin covers are susceptible to damage under impact of the falling ball. Panels in conventional-type doors are likely to be somewhat thicker and are thus less easily damaged than the covers of the flush doors. Shallow indentations are quite conspicuous in doors with very smooth or highly polished surfaces, but show up much less in rough or textured surfaces.

Impact by sandbag had damaging effects on most of the doors tested. A panel-type door with doweled joints was found to be somewhat less resistant than the flush types.

Among the panel-type doors, the through mortise-and-tenon construction appears to give better performance than that consisting of blind-mortised or doweled joints. Plywood panels are stronger and more stable than the type consisting of a single thin piece of wood.

Most of the strength and stability of flush-type doors appears to depend on the nature of the cover and on the strength of the glue bond between the cover and the edge frame. A wide variety of hollow-core doors appear to give nearly equivalent performance. It would seem, therefore, that the core is required only to space the covers properly and to provide them with lateral support against buckling under external forces.

FOR THE FUTURE

Most of the work to date has been specifically related to doors for interior service. The same requirements in the strength or impact tests may be applied to exterior as well as interior doors. Exterior doors, however, are subjected to more severe weather exposure, and further study and possible differentiation of test methods is needed in the tests involving exposure to changing or differential moisture conditions.

Standard performance-test methods and requirements are the underlying objective of the work now in progress. Information already obtained indicates suitable test methods and points out possible performance requirements. Test results, however, are not enough. Performance standards must also be based on knowledge and consideration of the way doors are used as well as the way they are built.

Research up to the present has been directed toward evolving methods of examining constructions already developed and built. Greatest value from research is realized when it is used to predict structural performance, to indicate before a door is in production whether it will be good or bad. When performance-test methods and standards are developed, the correlation between test results and construction details will be the next goal.

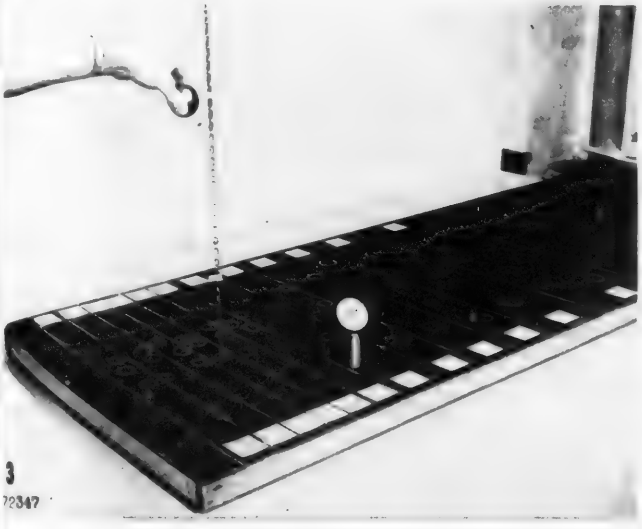

Figure 1.--Flush-type door in machine for racking-parallel test.

Figure 2.--Panel-type door in machine for racking-perpendicular test.

Figure 3.--Door with hardboard facings under impact test by the 2-inch-diameter steel ball.

Figure 4.--Panel-type door under impact test by the 10-pound sandbag.

Fig. 5--Cross section of conventional panel-type test door.

Fig. 6--Cross section of flush-type door with plywood face in which grain is horizontal and core of spaced, parallel wood strips.

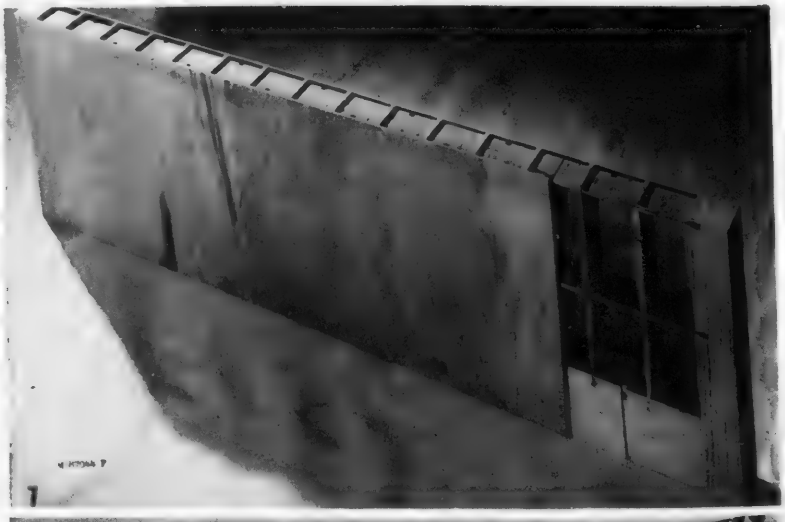

Fig. 7--Cross section of flush-type door with plywood facings and internal grid of wood strips.

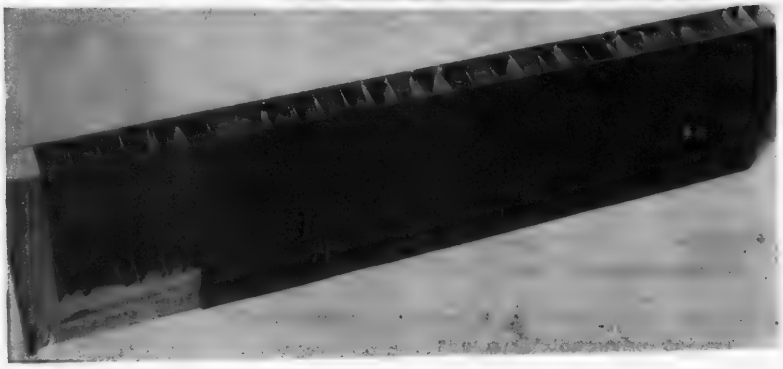

Fig. 8--Cross section of flush-type door with hardboard facings and core grid of corrugated boxboard.

Use of Small Logs for Veneer*

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INTRODUCTION

IN ALL PARTS OF THE COUNTRY, veneer manufacturers are confronted with dwindling supplies of peeler logs. As a result, logs formerly considered too small for cutting into veneer are now being used by the industry in increasing numbers. The diameter limits that define a small log or a large log vary, depending on species and region. On the West Coast, the softwood veneer and plywood industry was built around the utilization of large-diameter Douglas fir logs, and logs four to five feet in diameter are even now not considered unusual. A Douglas fir No. 1 peeler log must not be less than 30 inches in diameter and is expected to yield at least 50 percent of face veneer. A small log in this industry will range from 18 to 24 inches in diameter, and many mills have found it necessary and profitable to use a certain number of these so-called "peewee" logs along with the larger logs.

In the hardwood industry, the trend toward using logs of smaller diameter has been observable for many years. Acceptable diameters for high-grade logs have continued to decrease as the larger-diameter logs became scarce. Sometimes veneer manufacturers are pleasantly surprised with the quality of the veneer obtainable from small-diameter logs. For example, it is reported that smooth-bark yellow birch logs, 12 to 15 inches in diameter, make excellent veneer logs, whereas large old-growth logs are often defective.

As an example of the trend in the veneer industry as a whole, some figures from South Carolina, an important veneer-producing state, are applicable. In this state, the use of hardwood timber for veneer increased 53 percent from 1936 to 1946. The species involved were chiefly the gums, soft maple, and yellow-poplar. During this same period, the composition of the hardwood timber stand in South Carolina changed greatly in character. There was a decrease of 20 percent in trees 25 inches in diameter and an increase of 20 percent in trees 14 inches in diameter; trees 4 inches in diameter increased by 40 percent. This is an example of how the average diameter of the nation's timber stands is decreasing as the old-growth and large-diameter, second-growth trees are cut at an increasing rate. In order to survive, the veneer industry must turn to the use of timber of much smaller diameter than it has used in the past.

With the increased use of smaller logs of the desirable veneer species, other species, little used in the past because they do not attain large diameters, may receive consideration by the veneer manufacturer. Examples of such species are aspen in the Lake States, white birch and red maple in the Northeast, red alder in the Northwest, and second-growth pine in the South.

As this transition to smaller logs occurs, problems arise to which research must be applied if industry is to take advantage of available timber supplies effectively. The characteristics of small second-growth logs of the desirable veneer species need to be studied, for the wood may vary markedly in density, texture, and strength from that obtained from the slowly grown portions of old-growth timber. The growth characteristics of the species in question should be studied to determine which species clean themselves of branches at an early age and thus may yield a good percentage of knot-free wood, even at small diameters. Further study must be given to the preparation of smaller logs for cutting into veneer, the process for cutting veneer from these logs on the lathe or slicer, the drying of the veneer, the gluing properties of the veneer and problems in fabricating it into plywood or other products, and finally, the behavior of the veneer when used for various applications. Veneer-yield data are needed in order to compare the yields from various grades of smaller logs with those from large logs. Log-grading rules should be revised, on the basis of scientifically obtained data, to permit the inclusion of small logs that are suitable for veneer.

Fortunately, the required changes need not be made overnight, nor is there a complete lack of experience in using small logs for veneer. In this country as well as in Europe, certain producers have been making veneer from small logs on equipment that is not radically different from that used for large logs. The attainment of maximum efficiency in cutting small logs, however, may require some further modification in equipment and methods.

*Presented at meeting of the Forest Products Research Society, Midwest Section, September 19-21, 1951, Oshkosh, Wisconsin.

ADVANTAGES AND DISADVANTAGES

There are certain advantages to be gained from using small logs. At the present time, perhaps the most important of these are availability and low cost. Where heating of logs is required prior to cutting them into veneer, small logs require only a fraction of the heating time required for large logs. It should be possible to select veneer-quality small logs more efficiently than larger logs, since the defects present are more easily detected. Because of the shorter lengths involved, it is often possible to cut out good bolts between defects and to reduce the wasteful effect of sweep and crook. Short bolts of small diameter can be held in the lathe with smaller spindles and chucks and, consequently, can be cut to smaller diameters.

Large logs, on the other hand, have generally been preferred for veneer. In many species, diameter is considered important in order to get the maximum volume of clear wood put on by the tree after the branches on the lower part of the trunk have died and fallen off. Moreover, in rotary cutting, a certain volume of the wood is lost in the form of core, and when cutting to any fixed-core diameter, the starting diameter is important in determining what percentage of the log is thus inevitably lost. The time required per thousand board feet for handling logs, peeling the bark from the logs, and charging the lathe is less with large logs than with smaller logs. Smaller log diameters and cores also mean shorter lengths in the lathe, since the length that can be held in the lathe without deflection decreases as the core diameter decreases.

VENEER-PRODUCTION PROBLEMS

Log Heating

Many species of wood, such as aspen, can be cut into veneer without being heated. With harder woods, such as beech, however, heating is essential. Beech cuts well when heated in water at a temperature of 175° F. A large beech log, two feet in diameter, when heated at this temperature until it attained a temperature of 150° F. at an 8-inch core, would require about 45 hours in the vat. A 12-inch log can be heated to 150° F. at a 4-inch core in about 13 hours. Moreover, the smaller the diameter, the lesser are the stresses that are developed during heating, and, consequently, heart-checking problems are less pronounced with small-diameter logs than with large-diameter logs.

In one European plant, the handling through the heating vat of small logs averaging about 10 inches in diameter is mechanized. Logs are rolled into a round-bottom tank from one side and are submerged and propelled through the tank by a motor-driven paddle wheel. Logs emerge continuously on the other side after having been under water for the proper heating period. This system is adaptable to small logs because they are not hard to move through the tank and require only a relatively short heating period.

One hardwood-veneer producer heats small logs efficiently in equipment built to handle large logs. Small logs are fastened together with chains into bundles of convenient size. Each bundle moves on a low truck to a crosscut saw, where it is cut into a series of bolt-length bundles, each held with a chain fastened previously. Each bundle is then lifted as a unit into the heating vat and, after being heated, is removed as a unit.

The Lathe

The cutting of small logs should preferably be done on a small, fast lathe. Because of the relatively small volume of veneer obtained from a single bolt, it does not pay to stop to make adjustments according to the peculiarities of individual bolts. Changing the knife angle or "pitch" as the diameter decreases is generally not necessary because of the limited range of carriage movement. Similarly, variable rotational speed is relatively unimportant. Therefore, many of the lathes that have been used for small logs, including some portable models, are relatively simple in design.

On the other hand, definite production increases can be obtained by reducing to a minimum the idle time required for charging and discharging the lathe. Hydraulically actuated spindles are helpful, and in some small-lathe operations, the processes of conveying the bolt, centering it in the lathe, engaging the chucks, starting the cut, and, at a predetermined diameter, stopping the cut and discharging the core, are entirely automatic. The importance of reducing the lathe-charging time can be appreciated when one considers that three bolts, each 12 inches in diameter, are required to yield approximately the same volume of veneer as one bolt 20 inches in diameter, the lengths and core diameters being equal.

A reference to the relationship between bolt diameter and the length of bolt that can be cut has already been indicated. On 4-to-8-foot hardwood lathes, 5-inch spindles are common. When cutting 8-foot lengths, it is often necessary to use chucks six to eight inches or more in diameter in order to grip the bolt securely. Smaller spindles and chucks may be used on shorter lathes. Another factor that affects

this relationship is the deflection or bowing of the bolt in the lathe due to the pressure of the nosebar along its length, which limits the minimum diameter of the core for any given length of bolt.

American lathe manufacturers make standard machines for cutting bolts as short as 24 inches. The maximum diameter of log to be turned on the smallest model is generally 24 inches. On these machines, the spindle diameters may be as small as 2 inches. On machines 30 to 36 inches long, spindles of 2-1/2-inch diameter are used, and on lathes 42 inches long, the spindle diameters are 3 inches or more.

In tests made at the Forest Products Laboratory, aspen-veneer bolts, 24 and 36 inches long, were held with 3-inch spindles and chucks, and satisfactory veneer, 1/16 and 1/8 inch thick, was cut. When cutting beech, a much harder wood, under comparable conditions, some difficulty was encountered because of the inability of the small chucks and spindles to hold the bolt firmly.

Some small lathes may be obtained in portable models; they may be used to advantage on species that do not require heating before cutting and where the terrain permits the moving of the equipment into the woods.

Veneer Handling

Handling veneer from short bolts behind the lathe is not difficult because of the relatively narrow width of the veneer band. To maintain speed, it is advantageous to have mechanical handling equipment. A simple, mechanical handling method that has frequently been used when cutting small logs is the reeling method, in which the veneer is wound on drums or spools that may be made from veneer cores. This method also provides for the storage of green veneer in rolls between the lathe and the clipper. The multiple-deck storage conveyors for handling green veneer between the lathe and clipper, as used on the west coast, may be faster and more efficient than the reeling system, but are generally more expensive and require more space.

Where it is desirable to have all sheets of veneer of approximately the same width, and where clipping for grade is not essential, a back roll on the lathe provides for the delivery of the veneer in sheets of constant width. Some veneer manufacturers build their own fixed-width clippers by mounting a knife in a roller of the proper diameter. This roller is then stationed behind the lathe, and the veneer passes under it on a conveyor belt. At each revolution of the roller, a width of veneer equal to the circumference of the roller is clipped.

Veneer Yields

Yields of veneer from small logs, when compared to log scale measured in board feet, may be relatively high because commonly used log scales do not accurately reflect the cubic volume of logs. Cutting to a small diameter will reduce the core loss and is essential to the attainment of adequate yields from small logs. Table 1 shows the yields in board feet of green veneer (each "board foot" being 1 foot square and 1 inch thick) obtainable from logs of various diameters, when cut to several core diameters as compared to the board-foot scale of the log.

Because of the possibilities of improving selection of logs, cutting out defects, and eliminating the harmful effect of sweep and crook when working with small logs, the quality of the veneer produced from these logs is not necessarily lower than that obtained from larger logs. One veneer manufacturer is cutting clear ponderosa pine veneer from the internode sections of small second-growth logs. Also, because of the short length, individual defects can be clipped out with less waste than would be caused by the same defect in longer veneer.

A veneer-cutting study was made at the Forest Products Laboratory on twenty 8-foot aspen logs obtained in northern Minnesota. The logs were from 8 to 11 inches in diameter at the tops and were cut to core diameters of 5-1/2 and 3-1/2 inches. The total log scale by the Scribner Decimal C log rule was 400 board feet, or an average of 20 board feet per log. The total yield of dry veneer was 563 board feet, or an average of 28 board feet per log. Thirty-seven percent of the veneer produced was graded as face veneer, free of all defects. Twenty percent was sound back, containing small, sound, tight knots and other minor defects. Forty-three percent was of poor quality, graded as reject back.

FURTHER PROCESSING

One disadvantage in utilizing the veneer cut from small bolts may be its short length. The usual method of increasing the length of veneer is by scarf gluing. A scarf joint is formed by cutting the veneer ends to be joined at a slope, or beveling them, then lapping and gluing the beveled portions. The slope may be four times the veneer thickness, or in better joints, it may be 10 to 15 times the thickness. Where strength is of primary importance, as in aircraft veneer, the longer scarfs are specified. The loss of wood that occurs in making scarf joints because of the overlapping is proportional to the length of the beveled portion.

Machines are available for making scarf joints rapidly. One German machine works

like a veneer clipper, except that the knife, instead of travelling vertically, comes down at an angle and cuts a scarf having a slope 1:4.5. Once started, the machine remains constantly in motion and cuts 960 scarfs per hour. Behind each such machine, there are normally four glue presses, each gluing 240 joints per hour. The entire battery of five machines is operated by four people.

Scarf cutting may also be done on the lathe itself by knives that are somewhat similar to end-spurring knives, except that they cut a bevel instead of trimming the ends perpendicularly. All veneer coming from the lathe is scarfed at both ends. It is clipped to standard width, dried, and glued into a continuous strip. This strip is then clipped to the exact lengths required for the product intended. These scarfs may be less accurately cut than those produced by other methods and may be damaged in drying and handling. Yet, the method is used very generally in Europe and during World War II was even used on thin aircraft veneer.

Another method of making large panels from short veneer is to make the plywood panels in small dimensions and then combine them into larger panels by gluing scarf or other types of joints. Such procedures are being used by West Coast firms, and standard equipment is available. In one such mill, edge-grain veneer is cut on fast, small box shook slicers, in pieces approximately six inches wide and three feet long. These pieces are glued into plywood panels three feet square, for such uses as wall paneling and cupboard doors. Requirements for larger panels are met by joining small panels with a finger-type glued joint.

The development of paper-plastic overlays for plywood may facilitate the use of smaller logs for veneer. Some of these overlays have good defect-masking properties, particularly over small, sound defects such as may occur when cutting to small diameters, or over patches, scarf joints, splits, and rough veneer. It is therefore possible to make a high-grade product for certain uses out of material that was formerly not considered suitable for face veneer.

USE OF SMALL-LOG PRODUCTS

Uses for short veneer cut from small logs are numerous. It may be used in veneer form for containers, and in most cases, the lengths that can be cut on small lathes will be adequate for boxes, baskets, hamper staves, berry boxes, and other types of containers.

Special-use veneer may be obtainable from some species. For example, in the Lake States, where good crossband veneers are at a premium, aspen appears to have the requisite properties for such a product. Crossbands for doors, table tops, and other furniture panels can often be relatively short, perhaps not over three feet long, so that length would not be a problem.

Flush doors are sometimes made with face veneer oriented horizontally instead of vertically. Veneer having good grain and figure can thus be used for this high-grade use in lengths of about three feet. Such door designs are not uncommon in Europe. In Finland, birch face veneer is regularly cut from small logs in short lengths, and doors made with these short face veneers have been sold in this country. They have an unusual and pleasing appearance, the pattern being somewhat similar to that formed when using matched sliced veneer because of the repetition of the grain pattern at frequent intervals.

Many other plywood products can be made of small panels. Flooring squares, furniture panels, cabinet parts, fixtures, musical instruments, appliances, patterns, signs, displays, athletic goods, trunks, valises, woodenware, and toys are examples of possible outlets for plywood panels of small size.

Table 1. --Comparison of potential veneer yields from small logs

Diameter of rounded top	Scale per lineal foot of log[1] (Scribner Decimal C log rule)	Yield of veneer per lineal foot of log cut to --		
		8-inch core	6-inch core	3-inch core
Inches	Board feet	Board feet (green)		
10	3.75	2.4	4.2	6.0
16	10.00	12.6	14.4	16.2
24	26.25	33.5	35.3	37.1

[1]Computed on basis of logs 8 feet long.

Design and Construction of Modern Glued Timbers *

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STRUCTURAL GLUED TIMBERS have been widely used in large projects throughout this country where they have been in use since the middle thirties. During these formative years a great fund of knowledge and experience has accumulated that now permits safe design and economical construction.

Forest products laboratories, research societies, lumber associations, fabricators, adhesive manufacturers, treating companies and timber technicians have labored to improve the product and promote its use.

Working stresses for glued timbers for wet and dry service and normal condition of loading and various grade combinations of fir and pine may be found in the lumber association standards. Like those for sawn timbers they are adjusted for other conditions of loading, such as snow, wind, earthquake, or impact. They apply alike to treated and to untreated materials.

The various combinations of grades have bending stress levels from 2,000 to 3,000 psi. and all combinations have an equal factor of safety. A timber designed for one combination is as safe and as durable as to another.

It has been the experience of many laminators that the lumber market affords a more plentiful supply of the medium grades and the nondense material than of the higher grades of clear, select structural and dense. Since modulus of elasticity and horizontal shear values are constant for all grades of a species it often develops that high bending stresses, and consequently the higher grades of lumber, have little or no advantage where shear or deflection tends to be critical.

In Douglas fir it has been found that best economy and quickest delivery are obtained by using combinations which have bending stress levels at or below 2,600 psi. The best practice is for a designer to specify stress levels rather than grades. Where size is restricted, where appearance is of major importance, where sharp bends are encountered, or where special preference is expressed it may be expedient to use other grades.

Working stresses for glued timbers are higher than those of sawn timbers of the same grade and species, because of the greater restriction and better distribution of growth characteristics such as knots. For dry service conditions, as encountered in most covered structures, there is also a substantial increase for dryness.

In curved timbers the working stress should be modified by the factors for curvature and for radial tension or compression where such apply.

Working stresses as given in the standards for glued timbers were developed by the Forest Products Laboratory in a four-year test and analysis program, and are approved by the entire industry.

The same allowable loads, stresses, and methods of design for bolts, connectors and other fastenings apply to glued timbers, as to sawn timbers.

Grading of laminations is performed to the standard and dressing rules of the lumber associations, and lumber for glued timbers can be purchased through regular channels and from commercial stocks. Standards do, however, have some requirements over and above those in the rule book, and for most combinations a minimum slope of grain is specified and restriction of grain or knot size must apply to full length of piece. Small sizes not customarily graded for structural use shall meet the provisions of comparable joist and plank sizes and additional requirements as set up in the glued timber standards.

Lumber shall be uniformly manufactured, shall be machine finished but not sanded, shall have a uniform thickness with allowable variation of 1/64 inch, and shall be free of warp, twist or other characteristics which would interfere with gluing operations. All laminations shall be two inches net or less in thickness. At the time of gluing the lumber shall be conditioned to a moisture content of not less than 7 nor more than 16 percent and the range in any one timber shall not be more than 5 percent.

Some laminators have sources of supply where stock can be secured which fits closely their laminating needs, while others purchase large supplies of commercial grades and then choose and

*Presented at meeting of the Forest Products Research Society, Pacific Northwest Section, March 12, 1952, at Seattle, Washington.

select in the shop, diverting to other uses that material which does not make good laminations.

Two-inch laminations are the most economical of glue, lumber, and labor and nearly all straight timbers or slightly curved timbers are made using this thickness. Where sharp curves occur in timbers then it usually is necessary to use thin laminations, and cost is always increased thereby.

Pressure.--The actual pressure to produce a good glue line must be adjusted to many variables, such as liquid qualities of glue and smoothness and quality of laminations. Where laminations are surfaced immediately prior to laminating operation, it is certain that good contact can be secured more easily and with less pressure than where considerable time has elapsed between planing and pressure operations. It is not the pressure that causes the glue to stick, but pressure produces conditions which are favorable to good contact and to uniform glue spread.

End joints in laminations occur in nearly all work, since lumber lengths are seldom long enough to avoid splices. The construction and location of end joints are of great importance to the strength and appearance of the timber. The principal features of the commercial structural end joints are given in following paragraphs.

Scarfed end joints, when accurately fitted, properly glued, and well scattered, do not require reduction in moment of inertia or effective net area in design computations. A one in twelve slope is needed for high stress portions in tension, and one in five slope for compression portions of member. In commercial work the use of standard scarfing machines often makes it expedient to cut all to the slope of one in twelve.

By extensive tests scarfed joints have been found to have a strength equal to ninety percent of the unspliced lamination. Another five percent reduction has been allowed for occurrence of more than one scarf in the same high stress portion of a member. The penalty for scarfs is not cumulative to other strength reducing factors, and since all combinations in the glued timber standards are of lumber grades which have a strength ratio of 85 percent or less, the plain scarf end joints add no weakness to the member.

Some specification writers require that scarfed joints in adjacent laminations be spaced a certain distance apart. It is evident that any dimensional requirement of end-joint spacing adds burden to laminating operations. For straight work this extra requirement may not mean much, but it is quite difficult to do on curved variable section members, such as Tudor arches.

Remember that strength ratio of scarf joint is equal to, or greater than, that of the lamination for all grade combinations listed in glued timber standards. Also remember that in most members only small portions for depth and for length have stresses which approach the strength ratio of the wood.

The requirement that scarfed joints be accurately fitted, properly glued, and well scattered was arrived at by the industry after most exhaustive tests and careful analysis, and should be relied upon as a sufficient control for safe work. Here again technicians have well taken care of an item that causes needless worry to those who are not conversant with the care and consideration that have been expended to obtain standards which assure adequate strength and yet permit commercial production.

For a definition of the term, well scattered, there might be considered the example of a full set of balls well scattered around on a pool table. Two balls might be found close together but in general the balls would not be grouped or bunched. Clusters of end joints in glued timbers detract from the appearance and so should be avoided.

Plain scarf joints are those with a straight bevel cut from top to bottom of lamination at a slope of one in twelve maximum for flatness and one in five maximum for steepness. All scarf joints waste material but permit the use of short length lumber. Scarfs are usually cut on special machines which must make a true square uniform cut and produce a beveled surface which has a smooth face equal to a planed surface.

Stepped scarf joints are used in the same manner as those with a plain scarf except that the portion of the thickness of the lamination occupied by the step is disregarded in the design.

A stepped scarf joint may be a combination of three steps and two bevels so arranged that a step is at top, center and bottom of lamination for depth and each two steps are connected with a bevel cut. Steps are usually made equal so that one depth only need be disregarded in design. Bevel cuts are to the same slope as a plain scarf would be for the same construction. The stepped scarf permits positive positioning, and is especially helpful in continuous operations where bundles of laminations are fed into high frequency electric gluing machines, since the step will pull along the trailing section.

Butt joints transfer no stress either in tension or compression portions of the member. Used in the tension portion, there must be subtracted 1.2 times the sum of the moments of inertia of those laminations containing butt joints in a single cross section. In the compression portions the

sum of the moments of inertia of those laminations containing butt joints shall be deducted. Butt joints in adjacent laminations shall be spaced at least ten times the lamination thickness.

Butt joints cannot be used in curved work, and it would seem that their use is limited to operations where scarfing operations cannot be performed or where bulky low stress timbers are being built. They are not economical for standard commercial work.

Pegged scarf joints are those with a plain scarf which has a hardwood peg as an aid to accurate fitting. The two adjoining scarfed ends are fitted in the dry and a hole is drilled through the joint which is taken apart and a peg is inserted in one hole and allowed to project so that, after glue is spread on the scarfed ends and they are slippery, the joint can be reassembled correctly. The peg adds no strength to the joint and this type is not used for pre-glued scarf joints.

Double bevel plain scarf joints are used by a large California laminator in the same manner as those with a single plain scarf. The double bevel type is made by cutting the bevel in one direction just to the center of the width of the lamination and then reversing the direction of the bevel for the remainder. Each end of the joining parts has this double reversing bevel which allows them to join properly. The slope of the bevel, and consequently its strength, is the same as single plain scarfs. The double bevel scarf seems to have positive positioning qualities and is patented.

Pre-glued joints allow full length laminations to be made before assembly and may add to the convenience of the work, although end joints glued in the assembly have been successfully used in extensive operations. Doubtless pre-glued scarfed joints are a necessity for curved work, and assembly glued scarfed joints should have the positive positioning aids of pegs, steps or double bevel. Butt joints cannot, of course, be pre-glued.

In times past some specifications have required that all scarf joints be pre-glued and that the laminations be resurfaced afterwards. Resurfacing adds both labor and material costs to the work but increases quality little, if any. It is now considered better practice to apply 1/64 inch thickness tolerance requirement to the joint as well as to the lamination and to leave selection of the method to laminator. The swing is now towards the pre-gluing of all scarf end joints in high frequency electric machines.

Fire resistance of glued timbers is excellent because they are of large size and have fewer connections. Structures of glued timbers tend to avoid multiple thin leaf members, connections loosened by shrinkage, and seasoning checks and splits where fire may enter.

Some persons who have not observed the action of fire on glued timbers fear that glue lines will melt and timbers quickly delaminate, but tests prove that such actions do not occur. These tests show that casein or phenolic glue lines do not break down in fires until the surrounding wood collapses under combustion. Casein glue will not flame or char more readily than wood nor will it sustain combustion. Resorcinol glues have liquid content volatilized during curing operation and residue will not sustain combustion.

On faces where glue lines are exposed, cracks form along the glue lines in the charred portions much like they do along seasoning checks in sawn timbers. It can then be said that under normal fire conditions glued timbers perform much as do sawn timbers.

The National Building Code of the National Board of Fire Underwriters, permits "properly glued laminated pieces in lieu of sawn timbers of the size specified" for "Heavy Timber" construction. The net finished sizes of sawn or glued timbers as listed in the standards of lumber associations for such construction are acceptable by NBFU for the corresponding nominal sizes. Thus it may be said that a 5-1/4-inch glued timber or a 5-1/2-inch sawn timber will conform to the 6-inch nominal timber requirement.

A recent fire destroyed the retail shed in the laminating plant of Timber Structures, Inc. at Portland, Oregon. The fire lasted about one hour but many of the large sawn and glued girders suffered only minor damage. Several 12-inch by 26-inch by 20-foot casein glued girders were removed from the debris and carefully examined. Measurements disclosed that only about 20 percent of volume and 30 percent of strength had been lost. Careful observation determined that no delamination had occurred and that both sawn and glued girders had performed alike. Many of these glued girders will be reused.

Treatment of glued timbers with preservatives or fire retardants is a broad field that has not been fully explored nor standardized in commercial practices. Much has been done with pressure treatments but much investigation and much work on the combining of wood, glue and treatment into a harmonious unit remains to be accomplished.

There are now certain patterns evolving which seem to indicate the general outline of the future picture. Treatments may be oil borne like creosote, or water borne like Wolman Salts or Minalith.

Oil treatment of glued timbers seems to be a satisfactory operation and many bridges and other outdoor structures have been built using this type of construction. Pressure treating with creosote does not materially weaken or injure the glued timber and here we have an operation which works equally well with sawn or glued timbers.

While some structures have been built using water borne treatments on glued timbers, the results are not yet entirely satisfactory. If the treatment is applied to a completed timber there is an increase of moisture content which cannot help but have some disturbing effects. Raised grain, dimensional changes, checks, discolorations, and glue line strains are sure to occur. No longer do we have a good appearing seasoned timber that had so many superior qualities to a sawn timber.

Laminations can be treated with water borne solutions and then glued together into timbers. Always the laminations must be dried and resurfaced after treatment and there is the cost of the extra operations, and of course some treatment is removed. Also, some portions of the laminations are treated uselessly since only certain parts of the laminations are exposed in the finished timber. This method does, however, produce a more satisfactory product than does the first method.

REFERENCES

The following standards give much excellent information on glued timbers and contain lists of references for other good literature on this subject.

1. West Coast Lumbermens Association. Standard Specifications for the Design and Fabrication of Structural Glued Laminated Douglas fir - 1951.
2. Southern Pine Association. Standard Specification for the Design and Fabrication of structural Glued Laminated Southern Pine - 1951.
3. National Lumber Manufacturers' Association. National Design Specifications for Stress Grade Lumber and Its Fastenings - 1951.
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The Crosby-Anders Mobile Mill *

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ABSTRACT

MODERN SAWMILL MANAGEMENT is being called upon to operate smaller stands of timber with a low sawlog volume per acre. A modern tool has been designed in the subject sawmill to meet the demands of present day conditions, which is revolutionary in that one fully integrated unit contains the means for sawing logs, edging lumber, and traveling from one set to another, all under its own central power unit. The author's company has utilized five of the above units for a year in their operations and has concluded that the mill is a definite asset to their concern. The mill has made it possible to perform selective cutting in stands that ordinarily would be submarginal. It is concluded that a mobile mill of this type is more applicable to the conditions found in the Southern States than any other harvesting equipment now known to be on the market.

THE NEED FOR THE MOBILE MILL

Modern sawmill management of the Southern States is now at the point where it must concede that we are in a new era of lumbering. We can recall when in the not too distant past, there were extensive stands of relatively large timber. Obviously such stands were more economically harvested with large operations that were set up more or less on a permanent basis, with all the economies that go along with a large scale, large volume production. As time went on, timber stands and log volumes became smaller, and the stands adjacent to many large operations were exhausted so that it became more economical to move smaller, more portable mills to the timber and often to manufacture the lumber at the timber site.

Today most lumbermen will find that their source of stumpage is derived from two, or one of two, sources. They will either operate on large tracts of timber, sometimes owned by themselves, or on small tracts owned by various individuals. In the latter case it is frequently found that the timber is of such size that it is more economical to haul the products in the form of lumber rather than as logs. We find today that, under the pressure of high market prices and intensive competition for stumpage, many submarginal timber stands are liquidated in such a manner that high manufacturing costs result in poor returns for both manufacturer and timber owner. It is obvious that it costs just as much to move a given sawmill to a tract containing a cut of 25,000 feet of lumber as it does to move to a tract that will cut 500,000 feet. This fixed cost, which is usually at least $150.00, must be written off on the volume that is manufactured. If this cost can be spread over many thousand board feet, naturally the cost per thousand will be less. A moving cost of $150.00 for a cut of 30,000 feet amounts to $5.00 per thousand board feet, which must be charged as a cost against cost of producing lumber from the particular tract of timber involved. Thus, other factors being equal, the return from smaller tracts of timber are normally much smaller than the returns realized from operating a larger tract of timber.

One practical result of the foregoing is that owners of small woodlots and patches of timber are often denied the opportunity to cut their saw timber selectively. They frequently can not induce a small sawmill operator to purchase their stumpage unless he is allowed to clean-cut the timber. In this very practical and all too common situation, the mobile mill has a direct application for it is designed and constructed for the purpose of enabling it to be moved from one location to another at a minimum cost. By measuring up to this prerequisite the mill becomes a most flexible tool in the hands of the sawmill operator and the timber manager to whom the operator looks for his supply of raw material.

This "superportable" mill (Fig. 1) has application to larger tracts of timber as well as to the smaller tract just discussed. Within large tracts the mobility of the mill makes it possible to operate small portions that are marked for thinning. It is more readily adaptable to operating in scattered stands or thinly marked stands of low volume per acre than the conventional portable sawmill. As an illustration of this, there are readily available examples wherein the timber owner was forced to sell his small saw timber as pulpwood in order to obtain a proper thinning. This, of course, accomplished the desired result but at a considerable loss in stumpage values to the timber owner.

*Presented at meeting of the Forest Products Research Society, Deep South Section, November 23-24, 1951, Shreveport, Louisiana.

TECHNICAL DESCRIPTION OF THE MOBILE MILL

With the foregoing as a background, we can turn to a more technical description of the mill itself and discuss how it has adapted itself to the requirements of present day sawmilling conditions.

Essentially the mill is composed of a Corley standard 395 sawmill and Corley, Jr. edger mounted on a steel tubular framework. This frame and component parts then are mounted in turn on a 12-foot chassis with dual wheels in front and tandem dual wheels in the rear. These wheels are driven by power from the main drive motor, a standard four-cylinder G. M. diesel, which also drives the sawmill and edger. The above chassis is adapted from that of the familiar G. I. 6 by 6 heavy duty truck. The sawyer, when moving the mill, can shift into a six-wheel drive for maximum traction, or can shift to a higher gear ratio for covering the ground up to 15 mph. on good surfaced roads. The above arrangement makes it possible to move to a tract of timber, make several sets on the particular tract itself, and then immediately, upon finishing the tract, move directly to another distant location with a minimum loss of time involved in pulling up the mill and setting it down again.

Hydraulic Lift System

One of the specific features that render the mill so flexible is the ingenious hydraulic system incorporated in it. Hydraulic cylinder and piston assemblies are located at the corners of the mill which make it possible for the mill and supporting framework to be raised off the ground for moving and lowered when in place, so that there is little weight on the tires when sawing. This hydraulic lift system has the further advantage of allowing the mill to be tipped or tilted along its axis so that it is possible to keep the saw carriage level for sawing even on hillsides or sloping ground.

Retractable for the Road

Fully extended and in operating position the unit is about 44 feet long. However, when moving (see Fig. 2) it is possible to reduce the overall length to 30 feet. This is possible by actuating a crank which causes the entire edger assembly to slide back on a track and retract toward the rear of the mill. Further, each end of the carriage track has been devised so that it may be unjointed and removed thus shortening the overall length considerably.

Carriage and Ramp Features

Another feature of interest is the endless chain log conveyor which is a fully integrated part of the sawmill. This conveyor derives its power from the main drive motor and is actuated by the sawyer to move logs rapidly up to the sawmill carriage (see Fig. 1). This eliminates the construction of log ramps and saves much time ordinarily spent in rolling logs on the skidway to the carriage. When the mill is to be moved it is only necessary to swing the two arms composing the log ramp up on the mill. A "backing board holder," employed to reduce mis-cut lumber is operated by the log-turner to hold a cant, etc., firmly against the knees of the carriage. This simple but effective device consists of four "arms" which are raised up by a lever to press the cant against the knees. The sawyer sits on a seat directly across from the headsaw and at right angles to the direction of the carriage, where he is not hindered by sawdust and where he can see the face of the log. He is in complete control of the mill and can observe the entire mill crew.

Power Drives and Dust Chain

Power is transferred from the main drive motor to the various components of the mill by V-belt drives. These drives, belts, and pulleys are guarded by hinged steel covers which protect the mill crew from moving parts, but may be removed quickly for maintenance and inspection. A dust chain is built into the mill as an integrated part of it and is driven by power derived from the main drive motor. When the mill is to be moved, the dust chain is simply swung back so that it does not protrude and impede the progress of the mill.

Other Advantages

The substantial construction and the many component parts conspire to make the mill rather heavy. It weighs about 16,000 pounds, which however, is less than the weight of the lumber usually hauled in a good truck load. For moving it on very long hauls (over 80 miles) it has been found best to employ a low-boy trailer. A 52-inch headsaw is used and the mill capacity and operation are about the same as you would expect from a conventional Corley 395 mill. The all-steel construction of the mill insures that a high degree of accuracy can be maintained in sawing even when cutting lengths up to 20 feet. Once the mill is initially lined up for sawing, it is not likely to settle or get out of line. The mill is well adapted to cutting for grade, and heavy timbers up to 12 inches by 12 inches by 20 feet have been manufactured.

Cost Figures

It is the author's opinion that this mill could be built complete, on an assembly line basis, for about $10,000.00. The five units now in use were hand made and their cost is not a true criterion. Operation costs of the mill have been fairly well determined and the following figures are considered conservative estimates. Assuming a tract of timber containing about

65,000 feet, average tree size about nine inches d.b.h., with 1,200 board feet per acre, fairly flat ground with good logging conditions, and a thirty mile lumber haul, the cost would break down as follows:

	Cost per M.	No. of Men.
Timber Cutting	$4.00	6 (3 saws)
Logging (includes depreciation	4.00	4
Milling Cost	7.00	8
Lumber haul	6.00	2
Maintenance (fuel, sawteeth, lubrication)	1.50	-
Depreciation (paid to lessor of mill)	2.00	-
Insurance on men, etc.	1.00	-
	$25.00	20 men

It is somewhat difficult to compare the cost of the mobile mill with that of the conventional types because the mobile mills have largely been operating under timber conditions to which the conventional type mill cannot adapt itself. However, one of the present mobile mill operators previously managed a conventional type mill and he states that, without question, his average costs for the present type mill are $5.00 per thousand below that of the mill he previously ran. A graphic illustration of this fact was noted when the same individual commenced a selective cutting of a certain privately owned tract with his conventional type mill about two years ago. After a week of operation he determined that he was losing money and would have to terminate his operations. Shortly thereafter he acquired his present mill and returned to the same tract of timber where he was able to complete the cutting with a margin of profit.

Another specific incident pointing up to the relative efficiency of the mobile mill occurred last winter when about 75,000 feet of timber was placed on the market for a selective cut. A conventional type mill operator bid six dollars per thousand more to cut the timber than the operator of the mobile mill who, of course, was awarded the contract.

It is apparent that the significant saving in operating costs is due to the relatively limited amount of logging equipment required to log for the mobile mill as compared with that required for the conventional type mill. The mobile mill can move to the logs; generally little more than five or six thousand feet will be cut at one set, and three or four mules sometimes supplemented by a rubber-tired tractor will skid the logs to the mill's log conveyor. To obtain the same production, the conventional type would have to employ two or three logging trucks, teams, or a log loader, and possibly a track tractor. The overhead, investment, and maintenance in this equipment is substantially greater than that required for the mobile mill. Some operating costs are saved too because fewer men are necessary at the mill. The mobile mill normally operates with eight men while most conventional type mills observed required from 10 to 12 men.

GENERAL CONCLUSIONS

After practical experience with the operation of five of these units for a year, our company has reached the conclusion that they have been a substantial asset to our operations. We feel that by employing these mills we have been able to perform timber stand improvement work in many instances where, heretofore, there simply was no tool available to do the job. In other cases, it is certain that we have performed such selective cutting at a lower cost than we would have ordinarily had to pay. Further, the flexibility of these mills has made it possible for the operators themselves to purchase a great deal of timber, previously denied them, which they then manufactured and delivered to our concentration yard.

The mobility of the mill gives it many advantages other than those previously noted. It allows for more sawing days. The mill can readily complete one job, move to another and saw for several hours on the latter job all in the same day. This cuts down on overhead and various fixed costs. Another important feature connected with the mobility of the mill is the fact that no fire is necessary to burn refuse material. The mill moves frequently and relatively small piles of slabs and sawdust are left in its wake. These deposits of waste material in the aggregate amount to no more than that produced by a conventional type mill and studies show that the total area occupied by the waste is no greater than the area demanded by the conventional mill. The small piles of refuse are assimilated quicker and allow tenants on farms a good source of fire wood, etc. This feature along with the lack of fire in the woods has great appeal to timber growers and we find that it has helped us occasionally to purchase timber. Further, many timber owners feel that heavy trucks and crawler tractors, are detrimental to young growing timber and the fact that only mules are required to log for this mill is a point in its favor. A resourceful operator learns to use many techniques with the superportable mill that will cut his operating costs.

For example, when it becomes necessary to cross a ditch or creek the operator of the portable mill doesn't bother to build a time consuming bridge, he simply makes a sawmill set adjacent to the creek bed and fills the ditch with slabs. He then makes a runway of the slabs and walks the mill across to the other side.

There are some disadvantages of the mill that should be mentioned. It has been said that the mill is more complex than the conventional type mill, thus requiring a higher degree of skill to operate it. This is certainly true; the mobility and flexibility of the mill is not to be had without the many necessary components that make these desirable features possible. By the same token, it could be said that the more conventional type mill is more complex and requires greater skill than a handsaw. Further, there is naturally more maintenance than is required for the conventional mill. There are numerous subassemblies which require frequent lubrication. The motor requires more than ordinary attention because of the job it is called upon to do, and care and sound judgement must be exercised in moving the mill.

Fig. 1. Portable mill in operating position with log ramp down and dust chain swung outboard.

Finally, it requires good management to coordinate the logging with the sawing so that when the mill is prepared to move, the next successive set will have been previously located, and logging procedure determined so that there will be a minimum of lost sawing time.

The ultimate conclusion is that there is application and need for a more flexible portable sawmill. It is not claimed that the subject sawmill is perfect but it is certainly a step in the right direction. With all due respect to the several fine manufacturers of sawmilling equipment, this mill represents the one of the few revolutionary advancements in this type of equipment in many years and it was sponsored by a manufacturer of lumber products and not a sawmill machinery concern. It is felt that an appraisal of this mill will cause progressive sawmill management to demand it more and more, for through its utilization, benefits will accrue to the timber owner, the sawmill operator, and the consuming public.

Fig. 2. Portable mill ready for the road with edger retracted and log conveyor and dust chain swung inboard. Chassis has been raised for travel by hydraulic lift system.

The Genetic Approach for Improving Wood Qualities of the Southern Pine

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INTRODUCTION

FOREST GENETICS is a new and relatively untouched field of study. Recognized only in recent years, it is at the stage of development where agricultural genetics was 15 or 20 years ago. A large number of people interested in forest genetics discuss its potentialities, often in glowing terms, and feel it is the answer to most difficulties encountered in forestry work. Up to the present time, however, much has been said, but little has been done about forest genetics so that research, and funds for research, are scarce. There also is a sizeable group of people who think it is a lot of nonsense and often say so. Although they will admit that an understanding of genetics has done wonders for our crop plants, they somehow fail to understand that a tree is a plant and its genetic behavior is similar to that of other plants. We must, then, take a middle-of-the-road view and realize that forest genetics can be a valuable tool, but that it is not a cure-all, especially in view of our present techniques and knowledge.

It should be understood that I am not a wood specialist, particularly not a wood physicist. Wood, however, is the product of a tree's growth process, and the manner in which the growth process operates will determine the kind of wood that will be produced. Growth is controlled primarily by the genetic make-up of the plant concerned. Therefore, in the final analysis, the type of wood produced will be determined by the genetic makeup of the tree and by the manner in which this genetic makeup reacts with the environment.

Before we go on with any discussion involving genetics, there is one point that must be made clear with regard to the roles played by genetics and environment. Basically, every function, every form, and every product of a plant is controlled by the plant's genetic makeup. The important point I wish to make is this: the relative importance of the environment is completely dependent upon the rigidity with which genetic factors control the plant. If the genetic control is rigid, then changes of environment will have little effect. If the plant is loosely controlled genetically then environment may be so influential that the genetic control has little importance. Tree characters of the latter type are often spoken of as being environmentally controlled. While this is partially true, it must be kept in mind that the environment can operate only within the framework of the genetic control. To illustrate this point, I shall use size of tree and shape of cone. If identical loblolly pines were grown on extremely good and extremely poor sites, the cones produced by the two trees would look similar (although they might vary in size) since cone shape is rigidly controlled, genetically. The tree on the better site would grow to a larger size than the one on the poor site since tree size is loosely controlled genetically. Tree size, however, will ultimately be limited by the genetic potentialities of the tree. If these same trees were planted under the most ideal conditions imaginable, they would grow only so large -- they could never take on the size of a giant redwood. The genetic makeup of the tree prevents unlimited growth.

GENETICS AND WOOD PRODUCTION

With the recent trend toward specialized uses of wood a need has been felt for wood of a type that is rare or has been depleted from our present forests. This need was recognized some time ago, and a small start was made to remedy the situation by a silvicultural approach where variations in stocking, thinning, pruning, and other practices were used. This has yielded a limited degree of success, but it has now been shown that the silvicultural approach is not enough. In the last few years, some of the more progressive foresters have cast envious glances at the agriculturist, who, if not satisfied with the plants he had to work with, goes out and by the proper choice of parents produces the desired plant by selection and hybridization. For example, if he has a desirable wheat that is not rust resistant and a rust resistant wheat of no commercial value, he can cross the two and by later selections and crossing back to the desired parent produce a wheat almost exactly like the good parent, but which, in addition is rust resistant.

*Presented at meeting of the Forest Products Research Society, Deep South Section, November 23-24, 1951, Shreveport, Louisiana.

Up to the present time the recognition of the need for better trees has resulted mainly in the production of trees with better silvical characters, such as fast growth. Little has been done to improve wood quality as such. In Europe, Sweden in particular, genetic work has been undertaken to breed trees for special wood qualities, such as birch with figured grain. To date, these breeding experiments have had limited success.

The chief obstacle to genetic work with trees is the time element. It takes a number of years before a tree produces flowers; it takes much longer before one can definitely determine what kind of wood will be produced. The situation is not as hopeless as it would appear. Shortcuts are being perfected that speed up the processes a great deal. For example, it was formerly necessary, after producing a hybrid pine, to wait 10 to 20 years before that hybrid would itself produce pollen or seed. One method of shortening this time lag is to take the one- or two-year old hybrid and graft it into the top of a large tree that consistently bears good crops of seed. This scion then usually produces cones in three or four years thereby greatly shortening time required for making further tests. Several such shortcuts have been found and many more need to be worked out.

Shortcuts that enable us to speed up wood research, however, are not numerous. We cannot look at a small seedling and predict what its wood characters will be when the tree matures. Studies have been made whereby such factors as limb form and rate of growth can be predicted from a seedling which has certain characteristics. No such technique has yet been found for wood characteristics, so apparently all that we can do is to wait until the tree grows to merchantable size. This is especially true for pines, since the first formed wood in a tree is not normal, in a broad sense. Some pine trees require 10 or even 15 years before they settle down to produce what might be called typical wood.

What I have just said would indicate that breeding trees for specialized wood is almost a hopeless undertaking. The situation is not as bad as it appears, however, for we have had a wonderful experimenter and ally working with us ever since trees were first established. This ally, Nature, has over the centuries produced trees with various desirable wood characters. Our job is to find these trees; then by proper breeding and selection, start on a program of producing individuals with these desired characters. We can at least produce individuals that we predict will have the desired characteristics even though the proof will not be forthcoming for a number of years.

IMPROVING SOUTHERN PINES

While the title of this paper specifically mentions the southern pines, up to the present I have been speaking in broad general terms applicable to most tree species. Now lets get down to cases, and seek to answer the question "How can we improve the wood quality of the southern pines by genetic means?" Before this question can be answered, I should first explain what I mean by wood quality. To simplify this explanation, I am going to divide wood quality arbitrarily into what may be termed gross wood quality such as straightness of grain, freedom from knots, proper ring width, and internal wood qualities such as fiber angles, compression wood, strength, and density. These two wood quality "types" will be treated separately, although there is no sharp line of demarkation between them.

IMPROVING GROSS WOOD QUALITIES

I am happy to report that a definite start has been made in improving gross wood qualities by genetic means. Some of you are familiar with the "superior" tree concept, an idea initiated in Sweden which is spreading throughout the forestry world. Part of our tree improvement program in East Texas deals with this choice of "superior" trees and much of my time since arriving in the South has been devoted to their discovery and testing. The idea behind the "superior" trees is exceedingly simple. It is merely the choice of trees found in nature that have better form, better crown, smaller limbs, better height and diameter growth, and all the other characters an ideal tree would have. The superior trees are then used as the source of seed for later plantations. Although many foresters apparently think it is not so, we get the same results in forestry by continually harvesting the better trees and leaving the inferior ones to produce the seed crop that a farmer will get who always saves his nubbin corn for seed, and sells the best corn. It is a situation similar to that described by the famous Bible quotation, "As ye sow, so shall ye reap."

The superior trees are chosen to represent the best of what we know to be rigidly controlled genetic characters. These are both silvical and wood characters combined, and an effort is made to get as favorable a combination of the two as possible. In choosing superior trees, growth rate, ability to compete, cone production, ability to prune well, efficiency of the crown (i.e. ability to grow rapidly with a small crown), and straightness of bole are all weighed against one another. Thus the chosen superior trees have many of the better gross wood qualities.

Selecting superior trees is the most direct method for improving wood qualities, yet its final results can be no greater than the best trees we now possessin our forests.

Another approach to improving trees genetically is by hybridization. This approach is extremely valuable from the silvicultural standpoint, but is of much less value from the standpoint of gross wood improvement. This is especially true of the major southern pines whose woods are so similar that hybridizing them would result in little change. Hybridizing with pines from other regions would also have little value on gross qualities since, in my limited experience, there are few hard pines that can approach the wood qualities of the southern pines.

I should like to digress a moment and show how hybridization can be of value. In the West there are two pine species which have produced a hybrid that is superior to its parents under some conditions. One parent, Monterey pine, is extremely fast growing, but easily damaged by cold and drought. Knob-cone pine, the other parent, is a scrubby, very slow growing, but exceptionally hardy tree. The hybrid between these two (we have some over 60 feet tall) is fast growing and hardy. Silviculturally we have here, in effect, a new species that is adapted to make good growth in a habitat formerly unsuitable for either parent. Unfortunately, the wood of neither parent is exceptionally good and both parent species are very limby, as is the hybrid. If such a hybrid could now be made between, say, slash and knob-cone pines we might possibly produce a hardy tree with a useful grade of wood. Despite the propaganda of some geneticists, however, you normally cannot take two inferior trees, cross them and come out with something spectacular. All you can do is bring together the characters present in the two parents and hope that they recombine in a favorable manner.

What can be done to improve internal wood qualities? No one is qualified to answer that question since practically no experimental work of this nature has been done. This question will be discussed in the light of wood density or specific gravity, a problem in which we of the Texas Forest Service are interested, and on which we hope to initiate research in the future. The problem involving wood density raises the same question that was discussed earlier; i.e. how is density controlled? We know that the density of wood is basically controlled by the genetic makeup of the tree, but we do not know whether control is rigid enough to make feasible the production of races of pine with high or low density woods. Research in the past was geared to the idea that the environment was all powerful, and that wood density could be varied as wished by changes in growth rate, site, and so forth. Recently, I reviewed as completely as possible, the literature on wood density and its control. The literature is filled with many controversial statements. One author states that the density of southern pine wood is directly correlated with rate of growth. Another writer denies this and says the age of the tree is the controlling factor. One author shows how wood density can be increased by increasing the rate of growth by irrigation, while another shows how the density is increased by reducing the rate of growth by drastic pruning. In all experiments there was a large degree of individual tree variation, even though the environments were as uniform as possible. In most cases the seed source or genetic background of the experimental trees was not taken into account.

It is my opinion that much, if not all, confusion in research on wood density is explainable from the genetic standpoint. There are individual variations despite environmental changes. For example, one plantation of slash pine was recently tested, and, although the environment appeared to be uniform, trees with very light wood to extremely dense wood were obtained from that plantation. As I see it, there is only one explanation for such a result. That is, that the trees have inherently different qualities of wood density.

If trees are found that are inherently dense, then the problem is that of propagating these trees either vegetatively or by cross breeding to build up a true breeding race of trees that has dense wood. If it is found that genetic control of density is loose, then desired density changes must be obtained by silvicultural means.

The above example deals only with wood density, but in principle, it is applicable to all internal wood qualities. As was mentioned for gross characters, hybridization may also play a part in this phase of the work.

In summary, let me restate the important points covered. Wood, like all other parts of a tree, is subject to genetic control. The rigidity of this control is not known for many wood characteristics. Those gross wood characteristics that are controlled by tree form and limbiness can definitely be improved genetically both by selection and hybridization.

Internal wood characteristics need greater testing, but circumstantial evidence points to the possibility of their improvement by genetic manipulation. Wood researchers cannot afford to ignore genetic variables. If these are ignored there is danger that research will show confusing results that are not explainable without cognizance of genetic behavior. At the present stage of development, genetic research plays a small part in the role of wood improvement. Its future importance will be dependent upon the development of techniques and new knowledge of forest genetics, and a greater understanding for its need in wood research.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

A Look at Forest Products Research in Peace and War *

L. J. MARKWARDT, Assistant Director, U.S. Forest Products Laboratory [2]

IT HAS LONG BEEN widely demonstrated that research, when conducted with judgment and imagination, is a profitable investment. It not only pays for itself, but is responsible for much of our progress. It is indispensable in our modern economy.

Mr. T. A. Boyd, Research Consultant of the General Motors Corporation, refers to industrial research as the "change-making function of modern industry." Illustrative of this role of research as a profitable endeavor are the reports of the Johns-Manville Corporation that 56 percent of its current sales are in products introduced since 1928, and of the E. I. du Pont de Nemours Company that 46 percent of its gross sales in 1942 consisted of products which either did not exist in 1928, or were not then made in commercial quantities.

Thomas A. Edison is credited with having organized the pioneer industrial research laboratory in 1870. In spite of the recognized achievements by Edison, business was slow in following his example. An upsurge of research, however, followed World War I, and by the end of the 1920's there were more than 1,600 industrial research laboratories in the country. A similar upsurge followed World War II. A recent report of the National Research Council gives the number of industrial research laboratories in the country as 2,500, and the number of persons employed in them as 135,000. These figures, of course, do not include universities and federal research agencies. That there is much room for further research expansion is indicated by the fact that this total represents but one-seventh of the more than 17,000 manufacturing concerns whose gross sales exceed $500,000 a year.

Early Forest Service Research

Research in forest products had its early beginnings shortly after Edison's laboratory was established. It is interesting to review, in the light of present-day developments and background, the reference to forest products research in the report of the Chief of the Division of Forestry, B. E. Fernow, for 1891, and to note the broad concept of a research problem in correlating structure and properties that is still far from solved even with modern techniques.

"The largest share of the expenditure of funds as well as of the attention devoted to any particular work," states Mr. Fernow, "has been bestowed upon the investigations into the character of our timber trees, which were discussed more in detail in my last report under the caption of 'Timber Tests.' This caption, however, does not fully indicate the exact nature of the work in hand. While the testing of the timbers appears as the most conspicuous part of the work, and the more careful determination of average values expressing the strength of our wood materials is looked for with eagerness by architects, builders, engineers, and consumers of wood, these features constitute in reality the smaller part and by no means the ultimate object of the undertaking. This object is a two-fold one, namely first to find out in what relation the mechanical properties of timber stand to its structure and physical conditions, and thereby to find for practice means of judging mechanical properties from a simple microscopic or macroscopic examination; and, secondly, to find out in what relation structure, physical conditions, and mechanical properties stand to the conditions under which the tree is grown, and thereby to obtain knowledge for the forest grower as to the kinds of timber which will yield the best results in given soil and climatic conditions."

Mr. Fernow's report continues: "Forestry is by no means satisfied with the growing of trees, but is concerned also with the production of material of given quality. In the virgin forests species are found growing in widely varying conditions and hence of widely varying quality, but it can not be the object of forest management to follow nature in this particular. It must also determine under what conditions the best or the most serviceable quality of a given species is produced, and must encourage the production of the species under such conditions alone."

Research at the Forest Products Laboratory

The broad objective of forest products research, as we visualize it today, is to make our forest supplies go farther and serve

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*/ Presented at the Northeast Section Meeting of the Forest Products Research Society November 1, 1951, at Cambridge, Mass.

2/ Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

mankind better. What are some of the ways in which this is being accomplished?

Regardless of how forest products research is functionally organized, the field of work can be classified under four broad headings, as follows:

1) Wood as wood.
2) Modified wood.
3) Fiber products.
4) Chemical conversion and chemical constitutents.

Wood as Wood

Since the beginning of research on forest products, there has been a continuing demand for data on the mechanical and physical properties of wood of different species. Standard methods of test were developed, and today we have comparable data on the strength and related properties of some 200 of our native species. Through this and related research a considerable number of "weed" species, so-called because they had little or no market, have been brought into satisfactory use and command extensive markets. As the virgin-growth timber is being depleted, increased attention is being given second growth, both in the evaluation of properties and in the relation of growth conditions to properties.

Other early research was conducted on wood preservation to extend greatly the life of material subjected to decay hazards and to marine deterioration; and on wood seasoning to develop methods of reducing seasoning degrade and seasoning time, and of satisfactorily drying the more refractory species.

Over the years there have been literally hundreds of significant research accomplishments. Many of these developments to improve the efficiency of utilization of wood as wood are already well known. Some have opened entirely new horizons for wood construction. Included in this research progress, to mention but a few items, have been developments such as the following:

(a) Improvements in joints and fastenings, the Achilles heel of wood construction through the development of metal connectors and the establishment of design data. The research to develop these design data, now available in published form, has covered many details, such as design values for different species, effect of moisture content of the wood, the required side and end margins, connector spacing details, stress distribution and concentration under load, and the like.

(b) The development of synthetic resins to provide a wide variety of bonding materials for wood, with characteristics ranging from quick setting to high water resistance. Important also were the related developments in gluing equipment, techniques, and a more thorough knowledge of the essential conditions of gluing.

The advent of improved adhesives has made possible what is known as laminated construction and has made plywood a dependable structural material. But the commercial application of laminated construction brought with it many problems requiring further research.

While much was known about the effect of knots and other defects, further study was required to establish their effect on laminated members, as a basis for their limitation with respect to permissible size and location in the individual laminations; information was needed on methods of splicing laminations and the extent to which butt joints could be employed in inner laminations; the effect of prestressing as in members glued to curved form; tolerances in surface smoothness and moisture content of laminations in fabrication; and methods of test for evaluating the integrity of the gluing. Laminated products, in which larger units are fabricated from smaller pieces, range from laminated arches and large structural beams to such products as bowling pins, tennis racquets, and baseball bats.

(c) The development of the stress-skin principle in prefabricated house panels, to promote economy with high strength through the more efficient use of material. This principle is employed in one form or another in much of the prefabricated construction now being produced. It involves bonding of the facing materials to the interior stringers with water-resistant adhesives rather than nails, thus obtaining adequate strength with less than conventional wall and floor thicknesses. A high degree of thermal efficiency is obtained through insulation. Obvious advantages are factory fabrication of panels and simple and quick erection of houses.

(d) The development of light-weight paper honeycomb cores for sandwich construction, with application to prefabricated house panels, doors, and many other items. Substantial moisture resistance of the paper honeycomb is obtained by pretreatment with synthetic resins. Research already completed has given design data applicable to sandwich constructions employing honeycomb cores, the effect of different amounts of resin content on strength and water resistance, and information on the actual strength and stiffness of panels of different thicknesses and with various facing materials.

(e) Refinements in kiln drying, with special consideration to accelerated schedules. The

kiln-drying studies have resulted in a number of improvements in kiln design, in establishment of proper methods and requirements for drying different species, and in shortening drying time with minimum checking and degrade. Related studies have shown that wood can be kiln dried through proper control of drying conditions without injury to strength properties.

(f) Great savings in material and economy of shipping space through studies of shipping containers, usually accompanied by improved strength and resistance to rough handling.

(g) Marked progress has been made in the development of log grades and in their application, particularly for hardwoods, and work is continuing in this important field.

Modified Wood

Research during the past decade has shown some of the possibilities of modifying the properties of wood to provide a material with greatly improved characteristics -- particularly improved hardness and greater dimensional stability. These have included:

Impreg. --The treatment of wood with resin-forming materials, as a means of moderately increasing stiffness, hardness, and bending strength, the increase depending on the amount of resin absorbed and the penetration. Appreciable dimensional stabilization may be attained with certain types of impreg.

Compreg. --The treatment of wood with resin-forming materials and subsequent compression to afford a hard, dense product with many special applications, ranging from precision jigs and dies to shuttles and propeller blades. A high degree of dimensional stabilization is attained.

Staypak. --The densified product resulting from compressing wood across the grain to one-half or one-third of its volume by plasticizing the wood by means of heat at a certain critical moisture content.

Related to these modified woods, though a result of chemical conversion, is papreg, a resin-impregnated densified product consisting of laminated paper. A board of high hardness, strength, and dimensional stability is attained

Fiber Products

Most important commercially of the chemical conversion methods is that relating to the use of wood for pulp and paper. Research has demonstrated the possibilities of broadening the species base -- of finding ways to use new woods and so-called weed species -- even including scrub oaks. These woods are now being used in increasing quantities to supply our needs for pulp and paper and cellulose products.

The semichemical process that was developed through Forest Products Laboratory research provides greatly increased yields over the customary chemical methods of pulp production. The process is finding ever wider application, particularly in the utilization of hardwoods. More recently a new process has been developed from research on the kinetics of water and steam cooking and mild chemical treatments which is called the cold caustic soda process. From many hardwoods it has produced even higher yields of pulp than the semichemical process, and because it does not require steam or pressure and is economical of chemicals, it gives promise of great economy.

Research on the production of fiberboard, particularly on utilization of waste, has brought to commercial production a number of new types of fiberboard that meet a wide variety of use requirements. Activities in this field show a great deal of promise for the utilization of low-quality wood and waste to meet expanding requirements for low-cost sheet materials.

Chemical Conversion and Chemical Constituents

Extensive studies have been under way on the broad problem of utilizing wood waste in its various forms, by chemical conversion. One of the most important and promising investigations has been the conversion of wood waste to sugar by hydrolysis. The wood sugars may be reduced to molasses, may be used for the production of alcohol through fermentation, or may be converted to a high-protein food product -- yeast. Feeding experiments have been carried on in cooperation with various agricultural colleges to establish the effectiveness and palatability of wood molasses when substituted for cane molasses as a supplementary feed.

Other studies in chemical conversion have been directed toward the break-down of lignin -- one of the most abundant and least-used components of wood. Hydrogenation has shown the possibility of converting lignin into a great many components and products, some of which have been fully identified. Lignin research holds the key to highly significant possibilities in improved utilization.

War Research Problems

While research in forest products is usually geared to a peacetime economy, experience has demonstrated the importance of wood and wood-base materials in World Wars I and II. National emergencies with urgent time limits for results, have accordingly served to stimulate and accentuate research on various forest products problems. At times a review and analysis of presently

available data is called for to make it more readily adaptable to some military need -- at others an accelerated attack on a current problem is required -- and at still others the experience and background of peacetime research are directed toward the solution of special problems bearing on military applications. Military projects thus cover the entire field of forest products research, ranging from lumber procurement and specifications, special gluing and fabricating problems, design criteria and factors affecting strength, to chemical conversion problems such as nitration of pulps and wood sugar production.

While packaging is an important peacetime research field, it quickly commands greatly increased attention in time of war. Its function is to assure the transportation of the hundreds of thousands of items ot war material to their destinations in a satisfactory condition and at a minimum cost. In over-all scope, packaging covers protective treatment of various products, proper cushioning and cradling, and exterior container design and specifications. The products of industry are of little avail in operating war theaters unless they have been delivered in condition ready for immediate or future use.

These are but a few of the literally hundreds of research problems that have been undertaken or considered. And while the progress has been substantial and results have paid manifold dividends, there are even greater challenges ahead.

Some of the important problems challenging present and future research include:

(a) Search for nondestructive tests to afford new tools for quality selection of material, and quality control of fabricating processes such as gluing.

(b) In wood preservation, there is great need for cheaper preservatives of high toxic value, and more simple and more effective methods of treatment.

(c) A need exists for cheaper adhesives -- and adhesives with as yet unattained characteristics -- long working life, low-temperature setting without pressure, and perfect water resistance.

(d) Cheaper pulps with lower capital investment for manufacture -- further broadening of the species base to permit more extensive use of weed species and to produce satisfactory pulp from any kind of wood.

(e) Solution of the lignin problem -- finding ways and means to use profitably the vast quantities available of this component of wood.

(f) Modification of the hygroscopic properties of wood and improving dimensional stability.

(g) Improvement of harvesting and fabricating equipment and techniques.

(h) Development of improved log grades.

(i) Development of more effective fire-retardant methods and treatments.

(j) Wood waste utilization.

(k) The effect of temperature on the properties of wood.

Dissemination of Results

The results of research at the Forest Products Laboratory are disseminated by correspondence, by publications (duplicated pamphlets and printed bulletins), by consultation and conference, and by presentation of papers at meetings of various kinds. The magnitude of these services is illustrated by the extensive correspondence -- some 50,000 letters received and answered each year; and by the 3,000 to 5,000 technical visitors who come for personal consultation.

Mention should also be made that there was established a few years ago, at eight of the regionally located U. S. Forest Experiment Stations, what is known as the Forest Utilization Service. Special staff members of the stations who have specialized in forest products utilization maintain close contact with research developments at the Laboratory and serve to further the application of the results in their respective regions. At the same time they are in a strategic position to report to the Laboratory and other agencies on particular utilization problems of the regions on which research is needed. This Forest Utilization Service has in the space of a few years already established itself as an effective medium of promoting improved forest products utilization.

Cooperative Research in Forest Products

The Forest Products Laboratory is particularly well equipped for carrying on research in the various phases of wood utilization. A few of the special items of equipment are as follows:

Fourdrinier paper machine, with many special controls; laboratory-scale attrition mills; pulping equipment;

specially designed boxboard machine for making A flute, B flute, or solid boxboard; an infra red spectrophotometer; a battery of fatigue machines; testing machines ranging in capacity from a few pounds to 1 million pounds; dry kilns; high-frequency bonding equipment; a veneer-cutting lathe; a veneer dryer; hot presses for bonding plywood and for other applications; large and small hexagonal-drum box-testing machines; a digester for wood sugar conversion; fire-test equipment; tabulating machine equipment; a variety of temperature-humidity controlled rooms; and low-temperature cabinet equipment.

The question is sometimes asked, "Can the Forest Products Laboratory undertake cooperative work for industry?" The answer is, of course, "Yes." The Laboratory is authorized to make its facilities available both to industry and to other government agencies for research work in its field.

"Does anyone take advantage of its services?" Again, the answer is "Yes," for over half of the research under way during the current fiscal year at the Forest Products Laboratory is cooperative work. The Division of Pulp and Paper alone had some 45 industrial projects last year. One company has 5 separate active projects under way at the Forest Products Laboratory.

How does one go about establishing a cooperative project? The process is quite simple. One approach is to discuss the problem with the nearest Forest Utilization Service representative. He will be glad to make contact with the Laboratory, or if preferred, contact may be made directly with the Laboratory by correspondence. Another approach is visit the Laboratory and discuss the problem personally with staff members. An estimate of the cost is made and a cooperative agreement prepared outlining the work to be done and establishing the respective functions of both parties. There is no further formality, as the Laboratory has authority to consummate contracts, except with foreign agencies.

The Forest Products Laboratory, in accordance with U. S. Department of Agriculture procedure, reserves the right to publish the results of its cooperative research studies, but this does not necessarily mean the results will be published. Each case in considered individually.

Examples of industrial cooperative projects include:

(a) Studies of fire resistance of treated fiberboards.

(b) The paper-making qualities of special pulps.

(c) Instruction demonstrations in kiln drying and gluing.

(d) Courses in packaging (one course was given to representatives of a single company).

(e) Tests of the effectiveness of special nails and staples.

(f) Studies of the drying of bowling pin blanks as it affects the properties of the wood and the serviceability of the pins.

(g) Evaluation of strength of new construction materials and prefabricated structural units.

(h) Effect of fire-retardant chemicals on strength.

(i) Tests of the effectiveness of wood preservatives.

(j) Tests of glues and gluing procedures.

Research, of course, costs money, but it usually pays for itself many times over. It is thus an investment rather than an expenditure. In industry it is the stimulant for keeping up to date. It cannot be overemphasized that research is the "change-making function of modern industry."

Research in the Universities *

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INTRODUCTION

RESEARCH in all fields, including wood, is rapidly expanding as industry is confronted with increasing numbers of unsolved problems arising from the rapid pace of industrial change and development. Research facilities available to help find the answers to these problems are varied, but they may be grouped into the broad categories of industrial, government, and university. Industrial laboratories include the laboratories attached to particular industries, and the private commercial laboratories whose business is to undertake research and development projects for individual sponsors. Somewhat analogous to the industrial laboratories are the laboratories maintained by various associations to carry on research of interest to groups of industries in the same or related fields.

Each of these types of laboratories has certain functions which it can best perform. In general, the industrial laboratories are best equipped to handle the problems of their particular industries, especially those that involve trouble-shooting and the evolution of new materials and methods which affect their products. To some extent these laboratories can and do carry on fundamental long-range research but, with some outstanding exceptions, industrial laboratories generally, and quite properly, devote their attention to the problems of direct concern to industry.

Government laboratories usually engage in broader projects than those concerned with specific industrial problems, and many of these involve, usually some limitation, placed by the governmental bodies appropriating the money, on the amount of fundamental research that may be undertaken, particularly if the research has no forseeable practical applications.

Universities have the responsibility to educate, and to extend the frontiers of knowledge. This involves research of a fundamental long-range type which unearths new knowledge, much of which has no immediate application, but which generally is put to work sooner or later. University research is seldom of the developmental type directed toward the solution of a specific industrial problem, unless at the same time some fundamentally new information is needed to solve that problem.

This paper will attempt to point out the functions of university research, the manner in which it can be most useful to industry, and just as important, the fields in which it cannot or should not operate. A few examples of research in wood and related materials, carried on at the author's own institution, will illustrate the type of work best carried on by the university.

TIMBER CONNECTORS

When ring-type connectors were first introduced, design procedures were set up on the basis of the test data available. Certain aspects of these procedures seemed inconsistent and over-conservative, but they could not well be changed until a better insight into the behavior of connectors under load could be obtained. A research project was therefore undertaken to study:

1. The distribution of stress around the connector when loaded at various angles to the grain,

2. The action of pairs of connectors under various loading conditions.

The first phase of the problem involved a great deal of pioneering work in the application of strain gages to wood, as well as the use on wood of the technique known at stresscoat. Earlier thesis work had shown that strain gages, then in their infancy, could be used on wood, but stresscoat on wood was still an unknown factor. This research, therefore, was an excellent one for university work because it combined the search for new knowledge with the development of new techniques for finding it.

On the basis of the results, new ideas respecting the spacing of connectors were evolved and then tested in the second phase of the research. Recommendations were made, and on the basis of conferences with practicing engineers and of still further tests, final design procedures were drawn up and adopted.

*Presented at meeting of the Forest Products Research Society, Northeast Section, November 1-2, Cambridge, Massachusetts.

FATIGUE OF PLYWOOD AND GLUED JOINTS

When plywood and glued wood generally became suddenly important in the wartime aircraft program, it soon became evident that little was known about the behavior of plywood and of glued wood under vibrating loads. A project was accordingly set up in which specimens of plywood and of laminated wood were subjected to alternating bending stresses until failure occurred. The same procedure was followed with lapped joints. Some tests were carried out at high and low temperatures. Various types of resin adhesives were studied in this manner and considerable insight into their strength characteristics was obtained. At the time the tests were undertaken there were no standard tests for this kind of material, so it was necessary to develop the test methods and the types of specimens to be employed. The research, therefore, involved not only the finding of new information but the development of techniques for finding it.

GLUE-LINE STRESSES IN LAMINATED WOOD

Field experience with laminated timbers indicated that glue lines, or the wood nearby, sometimes failed when the wood was subjected to changes in moisture content. A mathematical analysis was therefore undertaken to ascertain what the stresses in a glue line would be when the wood tended to swell or shrink. The analysis showed heavy concentrations of stress at the outer edges of the glue lines, indicating that failure could be expected to start there, if at all, This, of course, is confirmed by experience. The analysis also showed what properties of wood are important in contributing to such stresses.

Although this analysis largely confirmed the observations of field experience, it helped to put such qualitative observations on a quantitative basis and to point out the important factors involved. It therefore contributed to new knowledge of a general nature.

COMPREG

When compreg was in its early developmental stages little was known of its mechanical properties, and the methods of making tests were not firmly established. The considerable interest in the material shown by the air forces made it necessary to carry on tests of a pioneering nature to develop the best ways to determine properties, as well as to evaluate various factors, such as resin content, species of wood, temperatures, and pressures, which affected the mechanical properties. Extensive tests were therefore performed for industry, many of them with new fixtures and jigs not previously employed. Although this was not a formal research project, the tests were of such a nature as to require equipment of a research nature not normally available in commercial laboratories. The university, therefore, was called upon to handle these tests as well as to give advice in a new, largely unexplored field.

In this connection, also, little or no information existed respecting the fatique behavior of compreg under vibrating conditions such as would be encountered in an aircraft propeller. A project was set up, therefore, sponsored by industry, to make tests of a variety of compreg-type materials. The results helped to indicate the range of stresses which would be expected to cause failure and gave insight into the combinations of wood and resin which would behave best under those conditions.

LAMINATED BEAMS OF SEVERAL SPECIES

Engineering analysis early indicated that in simple wooden beams the portions which required high-grade strong material were relatively small and that, theoretically at least, it should be possible to laminate fairly large quantities of relatively weak or low-grade species to produce beams as strong as solid beams of the high-grade strong material. The original research undertaken to demonstrate this hypothesis was aided by a lumber company which made available the necessary species and grades, including a South American species. In this instance, therefore, an idea was tested and information was developed which helped to broaden our knowledge of laminated wood, particularly as to the behavior of beams of mixed species.

HIGH-FREQUENCY CURING OF RESIN-WOOD COMBINATIONS

In our laboratories, as elsewhere, work was carried on quite early to determine the feasibility of using high-frequency fields to cure synthetic resins in glue lines and impregnants for wood. These early tests were promising enough to make it desirable to look for support for a larger research project. With considerable interest and encouragement on the part of industry, such support was given by a government agency. The resulting project developed fundamental information respecting the pertinent electrical properties of wood and resin, such as dielectric constant and loss factor, over a considerable range of frequencies. Unfortunately at the time, the publication had to be restricted and therefore could not be made widely available. Therefore, although new knowledge was developed, its free dissemination was retarded, which is contrary to the objectives of university research.

The foregoing examples illustrate the type of research which university laboratories can and should carry out. They can be duplicated by any university laboratory which carries on original research in cooperation with industry. Their distinguishing characteristic is that they develop new information of a general nature; that is, information of use generally to engineers and to industry. Each of the foregoing, for example, led to published papers.

WHERE THE UNIVERSITY SHOULD NOT FUNCTION

A type of work which university laboratories should not undertake is routine testing of a well-established nature for which facilities exist in commercial testing laboratories. Such testing, while it is essential for industry, does not lead to new information but merely evaluates a product. It therefore does not fall in the province of the university laboratory. Furthermore, the universities should be very careful not to put themselves in the position of competing unfairly with tax-paying commercial laboratories.

Another type of project which university laboratories should not usually undertake is the development of new products or pieces of equipment to order by industry. Such work should properly be handled by commercial organizations set up for that purpose and experienced in such work. Developmental projects seldom lead to new knowledge of the type the university should seek to develop. Furthermore, the university is not staffed or equipped to carry on such work. On the other hand, of course, new products and new devices often arise as the result of university research but even these usually need further refining and development by industry before they are ready to go into production.

WHERE OPPORTUNITIES EXIST

Cases often arise in which industry needs tests of an essentially routine nature but requires them so seldom that it is hardly worthwhile for a commercial laboratory to acquire the necessary equipment, whereas the university may have it as part of its research or classroom equipment. In such instances the university may quite properly carry out the tests for industry. A certain amount of such testing is desirable because it keeps the university staff in touch with industrial problems, but care should be taken not to do so much of it that the regular research projects or the class instruction suffer. The charges for such testing should be high enough not to discourage commercial laboratories from setting up the necessary equipment if the volume of testing becomes sufficiently large to be attractive to such laboratories.

Industries sometimes approach university laboratories with the suggestion that their problems might be given to students for solution. Usually the industry sincerely wants to offer the problems as practical examples for students to consider and to solve, but occasionally the motive is a desire for free or low-cost service. In any event, the proposition seldom can be handled satisfactorily on such a basis. Student help is not professional, and it may require so much overseeing on the part of the staff that the job could be done more expeditiously without student participation. Furthermore, class schedules seldom permit the necessary time to carry out all of the details of the problem which industry has in mind. It is far better to have the staff carry out the original problem and then later to use the highlights as examples in class discussion. This, as a matter of fact, is one of the most valuable uses of such testing projects and is an important reason why university laboratories undertake them.

When a problem arises which can well be handled by the university staff, several different kinds of arrangements may be made. If the problem requires primarily the time of a staff member and does not involve the use of the university facilities to any great extent, the staff member may enter into a private consulting arrangement. In this case the university has no connection with the project, and the arrangement is entirely the affair of the staff member, provided his university work does not suffer. Staff members are encouraged to enter into consulting arrangements, particularly if the work is of such a nature as to enrich the class discussions and to contribute to the development of the staff members.

AGREEMENTS COVERING THE RESEARCH

If the facilities of the university are to be used to a considerable extent a formal contract may be drawn up between the sponsor of the project and the university. Different universities handle such projects differently. Some state universities have engineering experiment stations, some universities have research foundations, and still others have special divisions or departments organized to handle projects sponsored by industry or government agencies. In any event, two of the key provisions in any contract are usually those respecting patent rights, and the use of the university's name in publicizing or promoting the results of the research.

No general statement can be made respecting provisions and each contract has to be examined on its own merits. Patents may arise from work which had originated before the contract was agreed upon but was carried to completion under

the contract. In such instances a judicious division of rights must be made. Patents may go outright to the sponsor, they may be retained by the university with special preferred treatment for the sponsor, or still other provisions may be made.

Universities must obviously avoid any implication that they endorse any commercial product. Contracts therefore provide that the name of the university may not be used in sales promotion or advertising. The same provision holds true of the names of its staff members, whether the staff members worked as private consultants or under university contract.

Publication of the results of a research project in the form of professional papers is quite another matter. Universities are reluctant to accept research projects the results of which cannot be published, unless the national security is otherwise endangered. One of the primary functions of the university is the extension of knowledge, and free publication is one of the means of achieving that function.

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Factors Influencing Wood Utilization *

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CHANGED THINKING FOR A CHANGING INDUSTRY

THE SUBJECT of wood utilization on the West Coast has become important in recent years because of a change in fundamental nature of the operations. Timber, once, readily available on an open market, began to be hard to obtain, companies started to build timber reserves, and the concept of a fixed raw material supply started to influence management's thinking. The realization that the forests were renewable stimulated an interest in second-growth lands and forestry management. All this marked a transition from a liquidation process to a sound business philosophy. This change in thinking has made a great deal of difference in our raw material supply picture. I have some figures available for the United States, indicating a drain on our forests of five times the annual growth in 1918 and approximately equal to annual growth in 1944.

This indicates an over-all balance between growth and drain. However, growth figures do not paint the whole picture, particularly on the West Coast. Here usage is predominantly virgin timber, whereas the future supply is exclusively second growth.

The growing cycle necessary to produce logs comparable to virgin timber is not an efficient one. Maximum yields per acre per year occur at much less time than is required to produce the large trees. Therefore, the raw material that is available in an area will change drastically at the start of the second harvesting of the forest. This is the major challenge to the development department today. It alone is ample to justify extensive research and development.

The ability of second-growth lands to produce good marketable timber on short cycles is also dependent upon efficient utilization. Second growth forest lands are best managed under a comprehensive thinning program. In order to produce maximum yields of higher quality, forest lands must be thinned and the thinnings utilized. It is necesszry to utilize the thinnings to pay for the cost of thinning. No company can see far enough into the future to risk spending many dollars to increase the quality of forest lands which will not be harvested for another seventy years. Utilization is therefore important to keep our forest lands producing at maximum rates.

In addition to the marked change in raw materials facing us, there are also the cold, hard facts of economics to be considered in a utilization program. Wood has held a very strong position historically in the building field and still continues to do so. However, as we all know, costs of producing wood products are increasing daily. Timber is also getting smaller as logging progresses to the higher elevations. Labor costs and overhead are increasing rapidly. Merchandising problems become more complex and expensive.

At the same time that wood production costs are increasing, the building industry is being encroached upon by a great variety of competitive products, some of which are able to offer characteristics which wood does not have. These new processes involve raw materials other than wood. Possibly the best example of this type of competition is that of aluminum. Prior to World War I aluminum was a laboratory curiosity and any one suggesting it as a building material would have been laughed at. However, in a period of forty years the price of aluminum has reached a point where it is making serious inroads in building construction and costs less than wood in many instances. I would like to ask a question as follows: What major development in the use of wood has occurred in the last forty years which can be compared to the development leading to the low cost of aluminum? I think that this should give us all some thought.

There have been, of course, other materials which have replaced wood in its traditional uses and which will continue to do so. The chemical industry in the United States is relatively young and vigorous. Competition from this industry is extremely rough. Research expenditures and "risk capital" are the highest of any field of business. We in forest products are prone to "business as usual" tactics. Any product competing with synthetics must be reviewed constantly, since the market will eventually go to the cheapest, other factors being equal.

The answer to competitive production as well as the high cost of forest products is utilization. The only way in which costs of producing wood

*Presented at meeting of the Forest Products Research Society, Northern California Section, October 8, 1951, at Eureka, California.

products can be held in line is by increased utilization and efficiency. As we all know, a major portion of the living tree is not utilized in conventional manufacturing processes and at best is utilized for fuel. The development of processes and products to utilize the left-overs from manufacturing operations, including logging, could increase the out-put of forest products with no further drain upon forest lands or, conversely, we could produce the same tonnage of forest products that we are producing now and decrease the number of trees which we are now cutting. An example of the point I would like to illustrate is given by the petroleum industry. The cost of oil production shortly after the inception of the oil industry was quite high, due to the fact that only a small portion of the total amount of material in the crude was utilized. However, with the great diversification of products, the proportion not profitably utilized has dropped considerably. This same thing can be accomplished in the forest products industry by utilization of more and more of the log. Obviously, logging costs per unit of product will be half of previous costs if production from the same amount of materials is doubled.

The need for utilization clearly established, the next major point of consideration is the raw materials available for the contemplated utilization process.

SURVEY RAW MATERIALS OF NEW PRODUCTS

The expenditure of considerable time and money in the development of information concerning these raw materials is a necessity. Possibly the first consideration is the quantity of material available for a processing plant. Obviously, a sound utilization program must be considered carefully in view of over-all quantity and quality of raw materials.

The source of the raw materials to be used in a process is of primary consideration because of cost. Refuse wood in a hog fuel conveyor in a mill costs much less to prepare than logging residuals. These costs can vary as much as ten times from the least to the most expensive, discounting any value of the wood itself.

The physical size of the wood is another important consideration. Physical size of the wood is the primary reason why we have wood left to utilize. The wood which will be available to utilization process will in general be smaller than commercial size, or of such a shape to make it unprofitable to handle. The method of utilization which is used will depend primarily on its physical size. Obviously, boards slightly under commercial size could be utilized by edge and end gluing to produce commercial-size yields. This same process would not be suitable for sawdust, for example.

After the wood is at the plant, the next consideration must be given to the cost of preparing the wood for the process. This might include such operations as washing, barking, chipping, etc.

Most of the development work on the process which utilizes formerly unused wood has been centered around the physical characteristics of the woody raw material. This is probably due to the fact that wood is an extremely complex chemical structure and certain portions of it have defied chemical analysis. However, the chemical characteristics of wood are as important a developmental factor as the physical characteristics and in the case of the predominant species in this area, namely redwood, it is possible that the chemical characteristics of the wood will out-weigh the physical characteristics when it comes to developing uses; therefore, the chemical characteristics of the wood should be known to the fullest extent before a program for development of the particular species is suggested. This involves an expenditure of relatively large amounts of research funds on fundamental research. Sometimes this is a hard bill of goods to sell to management but no comprehensive and well developed plan of utilization can come without this basic information.

ACCESSORY MATERIALS

Almost all processes require raw materials other than wood. Some of them involve only raw materials such as water and power; other require chemical raw materials in varying amounts. This paper will be confined to consideration of water and power, since discussion concerning chemical raw materials becomes too involved. However, it is always wise in these days to examine very critically processes from a raw material standpoint in order to determine whether or not the raw materials involved, other than wood, might be critical or not available during periods of national emergency.

The power used in processing plants varies greatly and my main reason for discussion of power as a factor in wood utilization revolves around the fact that quite a few forest products plants use residual wood for a power supply. As soon as utilization becomes more extensive, the pinch is on for power due to the fact that wood which has previously been burned is now being utilized. Therefore, at some point in the utilization program, the wood which is used in the utilization process has more value that it had previously due to the fact that oil or some other form of fuel must be used to produce the energy which was formerly being produced by the wood.

Cost of producing steam and electrical power will go up accordingly.

One of the most critical of raw materials in the whole United States, except in certain isolated areas, is water. A great number of processes for utilization of wood require quite large quantities of relatively pure water. I am thinking specifically now about various board and pulping processes. If a process is contemplated which uses water as a medium, considerable time must be spent in evaluating water resources in an area which would be available to processing plants. The mere test drilling of a few wells and pumping them for a short time is not necessarily indicative of the long range availability of water from a given water table and competent consultants should be used for this type of survey.

It is characteristic of most chemical processes that they manufacture by-products as well as the main product. Some times these by-products represent considerable problems in disposal. Possibly the best example of this is the sulphite pulping process where approximately one-half of the wood goes out the sewer. In general, forest products manufacturing plants are situated near large forested areas which are also used for recreation. This, coupled with the fact that forests are coming within the scope of public domain, means that considerable care must be exercised to preserve recreational and other commercial interests. Therefore, all processes considered should be examined critically with regard to their pollution potential.

Once an analysis has been prepared of the raw material available for a process, one must decide what type of process will be desirable for that particular set of circumstances.

STABILITY THROUGH PROPER PRODUCT SELECTION

The building industry has never been characterized as a steady business. There has always been either feast or famine. This was not a particularly serious problem when a company was operating on a liquidating basis; however, the concept of forest products industry is a continuing business has come into effect and the lack of stability in the building market has created considerable problems. Marketing of products other than building products demands continuity of operation. Also most forest products companies recognize their responsibility in stabilization of communities. In view of this fact, production other than in the building industry should be given serious consideration although it offers many more problems in terms of getting started and in merchandising. With a number of products going into entirely different markets, it is possible to off-set the extreme highs and lows of a normal building market.

Most utilization programs will result in products that are new to the company. For this reason, market research is a very important part of all developmental work. Frequently market research is done after the idea has been conceived and sometimes even furnishes the idea. Since the market and methods of marketing are generally unfamiliar to the company, this work should be done thoroughly and rather early in a program to prevent spending of developmental funds on a worthless project.

Most forest products companies are well set up to do a good job of selling conventional building materials such as lumber, plywood and doors. However, the introduction of specialized building material introduces a number of new problems in merchandising. Such items as insulation board and hardboard are sold upon entirely different premises than lumber and plywood and their merchandising is much more difficult. For new products outside the building field, merchandising becomes even more important. New products outside the building field are generally substitutes for existing products or products with an entirely new use and rightfully their place in the market can only be gained by intensive constructive selling. This selling must be done at every level from the distributor to the ultimate consumer. This is generally a new concept of merchandising to sales management and sometimes takes considerable emphasis to get the idea across. In many new products the merchandising development costs will far out-weigh the technical development costs. Many times a development program is predicated on the cost of developing a commercial product. This erroneous assumption has created a great many difficulties in connection with the acceptance of new products and has caused a lot of problems with new plants which are predicated upon making a profit immediately after the start-up period to get the "bugs" out of the process.

It is always hard for a person doing developmental research to admit that any department is more important than his own, particularly in new products. However, I feel it can be stated with assurance that the sales department is the most important department in development of new products, particularly if they are of somewhat novel end use.

THE ANALYTICAL APPROACH APPLIED

So far in this paper, I have been able to speak in generalities and have not been tied down to specific cases. However, I would like to apply

the principles of what I have said before to a specific case in redwood usage in order to illustrate points I have made. Probably the greatest expansion going on in the forest products line today is in pulp manufacture. This country seems to have an insatiable appetite for more and more paper products. Mills which were completed as late as 1949 are at the present time doubling capacity. The large amounts of woody raw material not utilized in the Coast redwood region seem on the surface to be a natural for pulp production. Certainly there is no question about the need for utilization of this material and it would definitely assist the economics in lowering the over-all unit cost of products produced by a company which is manufacturing only building products now. This product would help the company diversify its output in order to obtain and maintain economic stability. The wood raw materials are of such a nature that they could be reduced to chip size although some of the logging residuals would present problems in terms of cost of operation.

The chemical nature of redwood is such that it can be pulped by the kraft process of pulping. However, the yields of pulp from this wood are low, ranging in the neighborhood of twenty percent below the yields of woods well adapted to kraft pulping. It can therefore be seen that a pulping process using redwood as a raw material would be at a disadvantage in competition with a plant having a raw material better suited to pulping at the same cost.

In giving consideration to the raw materials other than wood which might be factors in a pulping program, probably the most important one is water. In order to manufacture unbleached kraft, water in the amount of 20,000 gallons per daily ton of production is necessary. Minimum economical size of a kraft mill at the present time is considered to be 300 tons; therefore, a minimum water supply of six million gallons a day is necessary. The amount of water required for bleached kraft is more than double the amount just mentioned. Water in this amount must be available every day of the year. It is to be mentioned here that bleached kraft is rapidly assuming more importance than unbleached kraft, particularly the bleached kraft which has been acid treated prior to pulping in order to produce a dissolving grade of pulp. With kraft pulping, as in most other types of pulping, there are by-products which can cause considerable problems. There are a number of mercaptans formed during the cooking and evaporating process and these products create an air pollution problem. Although the waste liquor is recovered in a kraft mill, efficiencies in recovery very seldom run higher than 92 percent and the remaining material is discharged in the effluent. In a bleaching plant, bleaching residues would have to be added to this. The relatively high biological oxygen demand of all residues requires large dilution in order to maintain dissolved oxygen concentrations at a level which will support marine life. Therefore, mills must be situated near large bodies of water. Even with large bodies of water, sometimes effluent concentrations reach a point where recreational advantages are impaired and public criticism, backed up by pollution agencies, will necessitate relocation of effluent lines, or will curtail operations.

A great number of mills with the large demand for pulp which we have had in the past few years, are contemplated or already under construction. Without a comprehensive market survey, it is not possible to determine whether the large demand for pulp which this country has had recently will continue. Prior to consideration of pulp producing facilities, a thorough market survey should be made. Merchandising of pulp is a rather highly specialized field and this factor must be studied carefully also. This applies particularly to dissolving pulp where quality is based on a uniform chemical analysis.

NO ROYAL ROAD TO UTILIZATION

It should be obvious from the above considerations that wood utilization is not something which can be ordered like a new piece of machinery. It does not come in standard size or stock models and the great many factors which affect wood utilization must be considered on the basis of individual company requirements. What is perfectly feasible for one company will be entirely unsuitable for another. The type of utilization desired will largely determine the type of staff required for the development program. In other cases, the men already available working under a competent research head, are able to work efficiently.

In closing, I would like to emphasize to companies contemplating a wood utilization program that the road to successful utilization is not easy, that considerable amounts of management time and money must be devoted to the problem. Above all, companies should be warned against the get-rich-quick proposals that are offered by unscrupulous individuals and some pseudo-scientific organizations. The only premise upon which a successful wood utilization program can be built is upon a sound scientific and economic basis.

Improved Utilization Needed for Louisiana Bottomland Hardwoods*

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INADEQUATE MARKETS for much of the wood grown in the forests of the Louisiana Delta constitute the major handicap to forestry practice in that region.

Other factors, such as the system of farming that has prevailed, the inherent suitability of the soil for cultivation, and neglect by the forestry profession, have contributed to the slow and as yet uncertain silvicultural development of bottomland hardwoods. But it was the considered opinion of a competent group of foresters, farmers, agronomists and soil scientists, who recently met and studied the matter of land use in the Delta region, that whether land is to be used for timber production or for other purposes is largely a matter of economics.

In other words whether or not forestry becomes a land use enterprise of importance in the Louisiana Delta depends upon the financial returns that can be derived from it. It also appears that the controlling factor will be the development of satisfactory markets for all wood produced.

DELTA AREA AND ITS HISTORY

When we speak of land use in the Delta we are referring to a major land problem in the state of Louisiana. The flood plains of the Red and Mississippi Rivers alone cover 8,308,594 acres or 29 percent of the land area of the state. Of the land in these two big river bottoms, 5,361,268 acres or 64.5 percent are still in woods. So what happens to these bottomland forests is a matter of major economic importance to the state.

The "front lands," the lands adjacent to or fronting the larger streams, which occupy a considerably higher topographic position than the lands away from the streams, were in cultivation long before the days of levees. With levee protection against overflows, cultivation expanded downhill to the edge of poorly drained and backwater areas. In recent years the Louisiana Department of Public Works in cooperation with the parishes has undertaken the opening of major drainage ways with the result that land formerly too wet for agriculture but unaffected by backwater is being cleared of timber. The point here is that essentially all of the land in the Delta is inherently suitable for cultivation or improved pasture. This land will be cleared of timber as rapidly as economic factors permit a solution of the water problems, that is, unless it can be shown that forestry can compete favorably with certain alternative land use enterprises in the matter of producing income.

This brings us face to face again with the need for improved utilization of the wood. There is not a chance that extensive forestry (as opposed to intensive forestry) can compete with the intensive agriculture that this kind of land supports.

SILVICULTURAL IMPROVEMENT DIFFICULT

Generally, Delta hardwood forests must undergo a long period of silvicultural improvement before production approaches anything close to their potential. Even then an appreciable part of the high production unavoidably would be in species and classes of trees that have little or no value under present market conditions. With stands badly deteriorated both in quantity and quality, in addition to the inadequate marketing situation, the job facing the present day silviculturist is discouraging and, under the worst conditions, practically impossible of accomplishment.

The Delta forests contain some eighty species of trees and large shrubs. Only about twenty of these species are in real demand and another thirty-five species are acceptable for rough uses at reduced prices. About twenty-five species have no utilization value whatever on present markets.

Past logging operations on most properties have taken out the sound trees of good form of the preferred species. The residual stands are too often composed of defective culls and undesirable species. To make a bad matter worse, wherever the loggers cleared too big a spot, the ever-present vines grow rapidly into an enveloping mass which makes reforestation impractical as judged by cost standards developed in pine areas.

While such extremely bad silvicultural conditions are not uncommon, they are by no means

*Presented at meeting of the Forest Products Research Society, Deep South Section, November 23, 24, 1951, at Shreveport, La.

universal. There are plenty of stands where the trees are of such size and species that the silviculturist could go to work if he could persuade the owner to undertake a forestry enterprise. Then there are many other stands under crosstie size that could be put into good condition quickly by thinning and the removal of inferior species and defective trees, if there were any market for such material.

Details of bottomland hardwood silviculture have not been developed to the extent that they have for southern pine because there has been too little practice. Nevertheless, application of the standard silvicultural principle of maintaining a proper growing stock of superior species would accomplish wonders if it were economically feasible. Only the merchantable fraction of the older stands can be manipulated. Treatment of good young stands must be delayed so long that much of the value of intensive silviculture is already lost. The forester has no practical recommendations now for the millions of acres encumbered with residual stands that markets will not have.

It has been emphasized throughout that incomplete utilization of Delta hardwoods appears to be the principal obstacle in the way of better forestry practice. Unless corrected, it may also be the factor that will cause cultivated crops or pasture eventually to occupy much of the now forested area. With fairly complete utilization of the wood produced, however, it is reasonable to anticipate intensive forestry practice and the permanent allocation of land to forest production.

PINE AREAS SHOW IMPORTANCE OF MARKETS

That such a viewpoint is warranted is confirmed by what has happened in the pine areas of Louisiana. Now that there is a ready market for pines of any size from a three-inch fence post on up thousands of landowners have become interested in forestry practices on millions of acres. They are managing the stands they have. They are planting at a rate exceeding thirty million seedlings a year and returning to pine trees much land once in cultivation or pasture. They are spending money to release young pines by deadening overtopping culls. They are doing all this because it has been demonstrated that pines pay; that pine trees are probably the most profitable crop for many upland situations. This would not be the case, however, if there were not a competitive demand for pine posts, poles, pulpwood and sawlogs.

It has not been overlooked that several paper mills within and adjacent to Louisiana use some hardwood. This market has little or no effect upon the bottomland hardwood utilization problem, however, because most of the hardwood pulpwood comes from the uplands as a by-product of pine operations. The demand for pine is so strong that alert sellers of pine stumpage take advantage of it by demanding, as a condition of sale, that the gum mixed in the pine stands be taken at the same time.

It is hoped that the Forest Products Research Society can be instrumental in developing profitable and extensive markets for all species and for small sizes of bottomland hardwood trees. A market for small sizes is most important. It it were profitable to operate young stands of the fifty-odd species now marketable, it would be possible and reasonable to take out unwanted species as weeds, just as unmerchantable hardwoods are now eliminated from pine stands. We might go so far as to say that the wide-spread practice of forestry in the Louisiana Delta region and even the eventual saving of the bottomland hardwoods as a national resource depend upon the development of markets that will utilize small-sized hardwoods in large volume.

Uses and Manufacture of Wood Flour*

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WOOD FLOUR is a product of dry wood waste, preferably in the form of sawdust and shavings to be ground and sifted to a very fine particle form, with no more than 10 to 12 percent moisture.

The first wood flour mill was built in Norway in 1906. The wood flour was produced by a stone attrition mill driven by a water turbine. This method makes a good grade of flour and is very economical.

HOW WOOD FLOUR IS MADE

There are many methods of grinding wood flour, such as stone mills, steel burr roller mills, single or double attrition mills, hammer or beater mills. The steel attrition mills make a very good grade of flour, but are unsafe because the heat and sparks create a serious fire and explosion hazard.

The majority of wood floor manufacturers now use the hammer mill or beater mill, reducing the wood by impact. These mills ordinarily consist of a horizontal casing in which a shaft is revolving at about 1800 rpm. Disks on the shaft are drilled to hold a series of 1/2 inch to 7/8 inch tempered steel rods which provide anchorage for free swinging hammers of tempered steel 1/32 inch by 2 inches by 6 inches in size. The hammers are punched on each end and may be operated over a long period of time, by changing as they become dull. The hammers can be reversed four times and sharpened by punching or grinding the dull points. A cutter bar is installed in the top half of the cover to break up the material.

The rapidly rotating hammers throw the material against the cutter plate. The material is then beaten by the succeeding rows of hammers until it enters the lower half of the cylinder, having a 1/64 inch to 1/8 inch perforated steel plate, containing holes of a size to pass the desired size of wood flour. The continual beating from inside the plate, assisted by suction on the outside, moves the flour from the grinder to the sifter for further classification as to mesh.

SCREENING

There are several methods of sizing the wood flour. The air separation method or oscillating and vibrating screens of sifters with silk or wire cloth are now used by the majority of wood flour manufacturers.

The air separation method is satisfactory for sizing wood flour of better quality that comes from a hammer mill.

The method of screening with silk or wire cloth is very satisfactory in the manufacture of wood flour from grinders. It is possible to screen flour up to 200 mesh. With this method one can make one grade of flour without accumulating rejects in the system, as they are recirculated through the hammer mills.

The grade of wood flour is designated by size or mesh. The sizes of wood flour most commonly used at present are 60-, 80, 100-, and 120-mesh. The finest wood flour marketed to my knowledge is 400 mesh, which is collected from the air cyclones or separators of the plant by several different mechanical and electronic methods.

HOW ONE PLANT OPERATES

The Spokane plant, of the Durez Plastic & Chemical Company which was built to manufacture 10,000 tons of wood flour a year from Idaho white pine may serve to illustrate modern plant operation.

The shavings are delivered by truck from the vicinity of Spokane, and by railroad from Nelson, B. C. and Huetter, Idaho. The first operation is the unloading of the shavings into a hopper supplying a Gruendler hammerhog in which the shavings are ground to rough size. This hammer mill is equipped with an electromagnet to remove foreign material, such as nails, spikes, tin and scraps of iron from the shavings.

The wood is then moved by air to a large storage bin of 80-ton capacity. It is conveyed from storage by a 30-inch screw and thence to individual conveyors which feed the Gruendler 24 by 40 hammer mills for the final grinding. These mills are also equipped with an electromagnet to catch any foreign iron or steel that might still be in the system.

*Presented at meeting of the Forest Products Research Society, Inland Empire Section, September 27, 1951, Sandpoint, Idaho.

The ground material is then moved by air through air locks or safety valves, which protect the system, then by screw conveyor to a large equalizing feeder, which distributes the flour to different sections of two Buffalo Niagara 96-section sifters. These sifters classify the flour and separate the rejects to be recirculated through the system. The finished product, 100 mesh or better, is then moved by air to the packing room where the flour is packed in 50-pound bags for shipment. An average of 1,200 bags are loaded in a 40-foot box car.

STATUS OF THE INDUSTRY

The future of the wood flour industry in the northwest does not look bright at the present time, as the high freight rates to the East Coast are detrimental to the industry. Two large wood flour mills have been built in the East during the past two years; one by Monsanto Chemical Company in Massachusetts and one by the Bakelite Company in Pennsylvania. These plants, which were built in the East to avoid long freight hauls obtain their raw material from the Northeastern states.

The expansion of production on the East Coast will be limited by the supply of raw material. On the other hand increasing population in the West will favor manufacturing plants in the West. For example, another large resin plant will be built on the Pacific Coast in the next year to meet the increased demands of plywood and hardwood plants.

There were only two wood-flour mills in operation in the Northwest prior to 1942. There are now six in operation. The production in 1940 was approximately 10,000 tons; in 1950 it was 30,000 tons, of which approximately 50 percent was 100-mesh. In the Northwest wood flour is now made from Douglas fir, ponderosa pine, spruce and Idaho white pine. Plants are in the process to make wood flour from cedar, which would be a specialized product.

Since the termination of World War II, representatives of foreign wood flour manufacturers have appeared on the American market. These representatives have made some progress in obtaining new business, as the flour is manufactured with stone attrition mills, and is of fine quality and suitable for plastics or linoleum. The linoleum manufacturers now require 100-mesh or finer for light-colored inlaid linoleum. However, domestic wood flour manufacturers have been progressive in adopting improved methods and are now able to make wood flour of as good or better grades than that of foreign producers. In fact, the 100 to 120 mesh flour made from Idaho white pine is the best to be found in any land.

The uses of wood flour are expanding and it is used now in the manufacture of dynamite, linoleum, plastics, glue, fine wallboard, face powder, leather cleaner, and many other products. The linoleum industry, which used approximately 40 percent of the wood flour until 1944, has long been the major consumer. Now the plastics industry is on a par with the linoleum manufacturers.

Wood Chips, Wood Chippers and Conservation Farming *

ARTHUR C. McINTYRE, Regional Forester, Soil Conservation Service, Upper Darby, Pennsylvania

RESULTS of research will not alter the fact that wood chips can be of specific service to farming. Experience of a few farmers, covering many years, has demonstrated that wood fragments, from both the agronomic and economic viewpoints, can be of service. Limited but supporting research findings indicate that wood chips can effectively be used as a chicken litter, animal bedding, compost material, mulch for crops, soil blanket to prevent erosion, and as a soil conditioner or amendment.

WOOD CHIPS AND SOIL

Of all the things man can do to curb soil erosion or impound rain none is more effective than those that maintain optimum amounts of organic matter in or on the soil.

When we talk about a soil or water conservation practice, we seldom use the words organic matter or humus. We talk abour crop rotations, cover crops, green manure crops, mulches, tree and shrub plantings, woodland and pasture management, and in so doing indirectly recognize that organic matter, living or dead, is responsible for predetermined desirable effects.

The protective effectiveness of organic matter in or on top of soil depends in part upon the percentage of lignin. Wood is high in lignin. A fragment of wood, of course, is quite different from a blade of grass and their conservation values, as organic matter, can be quite different.

Common to all types of farms is management of land, soil, and the production and use of organic matter. Soil management concerns itself with maintaining productiveness, which is basically dependent upon humic content.

It is well recognized that our farmed land is deficient in humus and that improved soil management practices must concern themselves with methods of increasing organic matter put into the soil. More humus is needed. That abundant life-giving force that trees, grasses, and animals impart to the upper few inches of the earth's fragmented mineral mass is called humus. This well-decomposed structureless substance gives a rich dark brown or black color to soil. Chemically it is complex, basically consisting of lignins, oils, waxes and resins and is referred to as a ligno-proteinate. Humus has many values. Primarily it is a soil conditioner. It influences soil structure facilitating intake of moisture and reducing run-off, and acts as a water reservoir. It prevents baking and cracking and excessive evaporation from the surface, and the fibre in it helps to prevent erosion by water and wind. The draft of implements is less, the quality of tilth better and less labor is required to achieve the ends of tillage.

The immediate effect of incorporating wood fragments in soil is to improve structure and water-holding capacity. Heavy soils are particularly responsive. Studies on a silt loam, low in humus, showed that sawdust plowed in at the rate of 8 tons per acre improved water-holding capacity by 15 percent and that water stability of aggregates improved 50 percent in two years. In an irrigated orchard on a heavy soil, the use of two inches of sawdust plus a green manure crop resulted in improving soil structure so that, in two years, one irrigation was saved.

Wood, like any organic matter, is attacked by fungi and bacteria, decomposing to form a humic substance depending in amount and kind upon mineral and lignin content. Woody materials also contain appreciable quantities of carbohydrates which furnish energy for the growth and activity of micro-organisms. The nitrogen content of woody materials is comparatively low. The micro-organisms that attack woody (or any organic) materials require nitrogen to make proteins for their bodies. Most of them cannot use atmospheric nitrogen and so must get it elsewhere. Consequently, when organic substances decompose in soil, a temporary shortage of available nitrogen is likely to occur unless it is made up. Under certain conditions, there may be a temporary phosphate deficiency. The N-P-K (nitrogen-phosphorus-potassium) value of wood is about 4-2-4.

Wood does not make soils sour or acid. When excessive amounts of some wood or bark are used a temporary acidic condition may develop but is of short duration. It has been found that the continued use of wood will raise pH values. The widespread idea that incorporating raw wood into

*Presented at meeting of the Forest Products Research Society, Deep South Section, November 23-24, 1951, Shreveport, Louisiana.

soil will make it acid is the most important single factor accountable for farmer reluctance to use wood fragments.

Organically, wood varies with species and age. It is composed of about 60 percent cellulose, 28 percent lignin, 1 percent mineral, and the balance, 11 percent, waxes, resins, and terpenes. Due to its high lignin content, wood can build up humus faster than herbaceous plants used as green manure or cover crops which are nearly all cellulose. Lignin alone materially improves soil structure and has been recommended for use as a soil conditioner. Lignin is highly resistant to the decay action of organisms.

Humus acts as a buffer to nitrogen demands. Soils high in humic content (3 percent plus) can more readily absorb free organic matter without reflecting depressive effects on crops than can soils low in humus. This further supports the desirability of maintaining optimum humic levels. The amount of nitrogen necessary to meet needs of organisms depends largely upon the amount of cellulose and size of organic material. High cellulose organic matter breaks down more rapidly than wood, which is rich in lignin. Decomposition is largely a surface phenomenon. Hence, the greater the surface area, as with sawdust fragments, the more rapidly organisms can work. And their demand on nitrogen is much greater.

It will not be necessary to use as much nitrogen when discing in coarse wood chips as when discing in an equal volume of sawdust. Studies on the use of sawdust as a soil amendment indicate that about 150 pounds of ammonium sulphate should be used per ton. One percent nitrogen has been proposed as a rule-of-thumb for sawdust. For wood chips about one-third this amount.

In using wood chips as soil conditioner their size can be governed and thus, in a measure, influence nitrogen applications. There is need for studies on the influence of size of wood fragments, soil type, and nitrogen requirements.

Plants can be grown in pure sawdust providing it is properly treated. Well decomposed wood has been particularly suited for certain greenhouse cultural operations. Under farming conditions as much as 20 tons of sawdust per acre have been used and crop yields have exceeded comparable fields where as much as 10 tons of barnyard manure was used. At a federal nursery 15 tons per acre is a standard application in routine soil management program.

Because conventional farming methods cannot maintain desirable levels of humus and because growing plant materials only for this purpose is costly in terms of land use, labor and materials, an alternative would be to draw upon surplus wood produced in the woodlot. In terms of the conservation objectives of using land in accordance with its capability and needs of the farm, such a practice has much to recommend it. Woodland products can improve and maintain values of plow and grassland and contribute to soil conservation.

MULCHING WITH WOOD CHIPS

There are three reasons why mulching is a good soil and water conservation practice; (1) it keeps the surface of the soil loose and friable, thus increasing penetrability and retarding runoff; (2) it absorbs the energy of raindrop impact, thus reducing erosion; (3) it reduces soil temperatures and thus conserves moisture by preventing or hindering evaporation. As a factor in maintaining soil porosity, mulch insulates the soil against early or quick freezes thus protecting worm populations. Mulching contributes to crop production and management by: reducing or eliminating weeds and grasses that compete with crops for nutrients and water; protecting plants from winter injury; protecting fruit from spattered dirt or cushioning its fall; and keeping soil from being compacted or puddled when demands of season, labor, and machinery necesitate operations when the soil is too wet.

Due to the multiple values of mulching, more farmers would adopt this practice if low cost mulch materials were available. An extension specialist reported that if a mulch material could be purchased for $8.00 or less a ton, 75 percent of the apple orchards would be mulched.

Studies have shown sawdust and shaving mulches very effective in the garden, berry patch, orchard and nursery. There are farmers who, after many years of using sawdust and shavings as a mulch and soil conditioner, know that wood fragments can serve agriculture. They have learned by doing. Some have pioneered. Their experience and "know-how" should be collated and publicized.

When an organic mulch is used, enough nitrogen to offset decomposition requirements should be supplied. If not, plants will be affected because they are deprived of nitrogen by demands of decomposing organisms. Six to seven pounds of a nitrogenous fertilizer (ammonium sulphate) per mature apple tree per year are enough when a 10-inch sawdust mulch is used. A rule-of-thumb is one-quarter pound of ammonium sulphate for each year of tree age when starting a new orchard and maintaining a 4 to 6 inch sawdust mulch. For blueberries an ounce of 7-7-7 applied twice each year, for each year of age, until a total of eight ounces is being used, has been found adequate. For strawberries, fifty pounds of an 18- or 20-

percent nitrogen fertilizer per cord of sawdust is reported acceptable. A 6-inch sawdust mulch will remain effective and require no maintenance for from three to five years. A chip mulch will last longer. Straw and hay mulches usually require annual care.

The cost of mulching will vary with the prices paid for material, labor and haulage. .In many communities throughout the forested regions sawdust is given away or sold at low cost. Its cost as a mulch, when starting a new orchard, has been computed at 45 cents per tree when using 18 cubic feet. Maintenance requires application of the same amount every three years. Cost per tree over ten years would be $1.80 or 18 cents per tree year. Wood chips can be made for less than $5.00 per ton. If they are used, cost per tree would be 70 cents for chips plus 45 cents for application, or $1.15 per stem. Cost for 10 years of mulching would be $4.60 or 46 cents per tree year.

Straw and hay are the commonly used mulch materials. It is seldom that they can be purchased for less than $10.00 a ton. Recommendation for mulching a bearing tree is 300 pounds with an annual maintenance of 100 pounds. Cost of material for a 10 year period would be $6.00 to which must be added application costs of labor and machinery, which would approximate $1.50. Tree year cost would be 75 cents.

It requires about 27 cords of sawdust or chips to provide a one inch mulch over one acre. A cord of coarse chips, produced from live trees, will weigh about one ton.

It is routine practice for orchardists to dispose of prunings by burning or dumping. Chippers and hogs coming into use provide for direct field disposal and thus leave the wood fragments as a mulch under or between trees. Chippers are now designed for mounting on farm tractors and utilizing power take-offs. Using these chippers, pruning costs have been halved. It is possible to move through an orchard with a tractor-mounted chipper and, by feeding pole wood through it, have the chips blown directly under trees to form a mulch. They can be blown onto the roadway and thus, in time, provide a pavement and aid in reducing compaction. Chips make an excellent road bed.

WOOD CHIPS FOR BEDDING AND LITTER

Bedding materials can be evaluated in three ways: (1) costs, in terms of production or purchase, and their handling in and out of the barn, (2) effectiveness as a bedding substance; and (3) agronomic value.

The costs of bedding materials are extremely variable depending upon kind and availability.

With the swing to grassland farming and acre reduction of grain crops, less straw or shredded corn stalks are locally available for bedding. In some sections of New England dairymen find that even sawdust and shavings are not produced in volume to meet needs. Wood chips are being used to provide an acceptable low cost bedding.

Cost of using various bedding materials, their storage, and the handling of resultant manures, are important items.

Wood fragments can be stored in bins readily drawn off into conveyors, thus reducing handling costs. They give better service than does straw when gutter cleaners are used. Sawdust, shavings, or wood chip manures are easily handled by spreaders and field distribution is more uniform than with strawy manures.

The most valuable characteristic of a bedding material is its capacity to absorb liquid manure. Studies have shown that sawdust and shavings will hold as much as hay, straw, or shredded corn stalks, In tests, sawdust has been rated first in handling quality and tendency to break up. Wood chips, because of their varied size and shape, will "stay put" better than sawdust, give a neater appearance to the stall and animals; produce little dust, and will not be readily floated away by liquid manure. It has been reported that there is less injury to cattle from slipping when chips are used.

Coarse wood fragments are excellent for use in the loafing barn. They provide a resilient and absorptive bedding. Fresh amounts can be progressively added and at season's end the mass of accumulated manure is easy to remove. Such coarse wood manures provide excellent mulch material.

Ten pounds of bedding per animal day is a general recommendation. This rate will produce a final manure containing from 12 to 15 percent of bedding by weight.

A ton of manure contains about 1,300 pounds of organic matter. N-P-K values will vary with the type of bedding. A wood fragment manure will contain about 13 pounds of nitrogen, 6 pounds of phosphoric acid and 12 pounds of potash.

The value of manure as a soil conditioner and conveyor of plant food is well established. It is also recognized that available volumes of manure are insufficient to meet the needs of good soil husbandry. The tonnage of manure can be increased by using more bedding which, on many

farms, would also improve barn management.

As the bedding content of final manure increases, the amount of N-P-K per ton would decrease, but any disproportion can be offset by adding these and other elements. When ten pounds of wood fragment bedding (sawdust) are used per animal day, about 40 pounds of ammonium nitrate or its equivalent should be added per ton of manure so as to establish an acceptable carbon-nitrogen ratio. It is thought that as much as 20 tons of woody manure properly treated can safely be incorporated in the soil at one time.

Heavy manuring is an excellent soil and water conservation practice. By increasing amounts of bedding an increased tonnage of manure becomes available. Wood fragments can meet the volume low-cost requisites to secure farmer adoption of this practice.

Wood chip manures will give as good mulch effects as strawy manures.

Wood chip manures fit very well into a grassland farming program. In contrast to strawy manures, they quickly sift down through the grass, where needed, and do not mat or have a tendency to blanket vegetation.

Wood shavings provide an excellent poultry litter. For broiler house use, coarse chips have been found satisfactory, and air-dried sawdust plus fine shavings are among the best of litters.

The type of litter desired varies with the poultry product produced and operators' experience. Wood chips, sized to meet requirements, can become a preferred type of litter material. They should rank first when judged in terms of the characteristics of good poultry litter. They will not pack and, because each chip has a tendency to shift or flip over when stepped upon, droppings sift through to the floor, thus maintaining a desirable cleanliness.

WOOD CHIP PAVEMENTS

Fragmented wood will make an excellent pavement. Erosion is often a serious problem where constant traffic beats out protective vegetation. Mud and puddles are common in denuded spots around barns and sheds where stock trample and machinery moves often.

Coarse wood chips can be used to provide a cheap and serviceable pavement. Run-off and puddling will be reduced, less dust occurs and good traction is provided.

On parade grounds, coarse wood chips have provided a resilient dust-controlled surface for a year under intensive foot traffic.

Wood chips can well serve on heavily used recreational areas by providing a ground covering which not only will improve appearances but lessen sheet and gully erosion, mud and puddle hazards, and reduce dust and dirt nuisance. On roads across fields where soil compaction is not desired, coarse wood chips can be used to provide a resilient ballast that can be added as needed and which will tend to maintain an acceptable zone for root growth.

WOOD AND COMPOSTING

Wood chips can be composted. Any part of a tree or shrub can be used to produce synthetic manure.

Because wood decomposes slowly, it is best not to compost it with other plant materials. To obtain the quantities of compost required to meet the needs of the organic farmer, the composting of woody vegetation is a possible solution. Using a wood chipper, the stems, branches, twigs and leaves of trees and shrubs can be sliced to small fragments, which can be piled and treated as desired. Wood fragment compost turns easily. It takes from two to three times as long to obtain a satisfactory compost of wood as from herbaceous materials. The tonnage produced is slightly greater when wood is used. On the average, about two tons of moist compost are obtained from one ton of air-dry woody material. A cord of wood chips should yield about three tons of compost.

A CONSERVATION TOOL

Accepting the fact that fragmented wood can serve farming in many ways, it still must be readily available and at low cost. Mills are not producing enough sawdust or shavings to meet requirements of farming.

Wood fragments could be produced at central points where chippers, hogs, shredders or hammer mills are operated, but handling of chunk wood and transportation costs tend to put a price premium on products. From the over-all standpoint, it is desirable to have a portable machine which can move to the farm and about the woodlot where wood is piled, thus affording farmers opportunity to harvest their own fibre crop advantageously.

Portable chippers are available and their successful use by a few farmers demonstrates that these machines can contribute to farming. Attention has focused only lately on these chippers as a conservation and farm tool. Early designs are being improved, resulting in increasing efficiency and flexibility of use.

WOOD CHIPS, WOOD CHIPPERS AND CONSERVATION FARMING

Operational studies show that wood chips acceptable for use as bedding, litter or mulch can be produced on the farm at low cost. More than two cords of pulpwood can be run through these chippers in an hour.

Summarizing management and cost items:

A cord of green pole wood weighs about two tons.

One man can cut and place in piles two cords of trees or long-length pole wood a day.

Chipping a cord of poles will produce about 240 cubic feet of chips. A cord of chips weighs about one ton.

Estimated cost per ton of chips loaded on farm truck -- $5.00, computed on the basis of paying $5.00 per hour for custom chipping, plus labor cost for cutting the pole wood. There are few localities where straw or hay can be purchased for less than twice or three times the cost of chips.

WOOD CHIPS AND FARMING WOODLAND

Nearly every farm throughout the forested regions has a woodlot. As a sound basis for soil and water conservation programs, land should be used according to its capabilities. The most valuable use for some farmland is to produce wood products and have on it a protective cover of woody vegetation. There is need for a sustained maximum yield of quality woodland products from these areas. From the woodlots, farmers should get enough wood for themselves and manage them for labor income. Every woodlot produces some wood that, because of its physical condition, is not merchantable. There are also those species having little or no market value. In many woodlots trees crowd each other and some should be removed to provide growing space. Any improvement or harvesting operation produces slash in the form of tops, limbs and other unused portions of the tree. From these classes of usually waste material, wood can be obtained for chipping and farm use.

The basic reason farmers are not responsive to the woodland management recommendation of farm forestry is the low dollar return for labor input. Farmers do harvest some wood from their woodlots for home use, but less than five percent of the farm woodland acreage is receiving adequate management. If wood chips can adequately serve where other materials are now used or where scarcities and high prices exist, the labor input return requirement can be satisfied. Then conservation programs will profit in two ways: (1) increased amounts of organic matter will become available to blanket the soil and build humus and (2) the farm woodlots, representing one-third of our commercial forested acreage, can profitably receive improvement treatments that they urgently need.

General acceptance of the routine use of wood chips on farms would be the greatest single factor to creating demand for farm forestry assistance and initiation of woodland management practices.

The requirements for acceptance of making full use of wood from the conservation, agronomic and farm management viewpoints, is dissemination of knowledge on "how" and by providing efficient machines that can convert trees into wood fragments that are physically adapted to meet requirements.

That wood fragments can serve farming has been satisfactorily demonstrated by a few farmers who have used sawdust and shavings for many years. Research has established facts in proof of successful farmer experience. Knowledge is not complete. Very few comprehensive studies on the several farm uses of wood fragments have been undertaken. If one-tenth as much attention had been given to the agronomic use of wood as has been given to any other crops, there would be fewer farmers and professional men believing that wood makes soil sour and should not be used as an organic amendment.

General and accepted knowledge about soil erosion, its cause and prevention, dates back but a few years. Yet in those few years, tremendous strides have been made in expanding and applying that knowledge. So it can be with the use of wood.

There is a Job To Be Done. Foresters, agronomists and soil conservationists should be concerned with its doing. Accomplishment will pay off in more applied forestry, better farming and more effective soil and water conservation practices. The job is to talk about Wood Chips -- Wood Chippers -- and Conservation Farming, and get a few farmers to using chips.

Sufficient information exists. It is the dissemination of knowledge that is now needed. More research is needed -- studies at all state experiment stations -- but is not presently essential to advocating the use of chips and chippers. Years of experience by enterprising, pioneering farmers have acceptably demonstrated that wood fragments can well serve farming.

The job is not a simple one because it is concerned with the habits of man --habits of thought and action. These are not readily changed.

Probably the best way to get the job going is to work with a few farmers in establishing demonstrations. In doing this, enlist the aid of county agents and others working with farmers. Publicize results and "let the chips fall where they may."

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Wood-Sugar Molasses as a Carbohydrate Supplement in the Diet of Livestock and Poultry *

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THESE QUESTIONS might be asked: What is wood-sugar molasses, how do we make it, and why are we concerned with it? Wood-sugar is a sugar concentrate resulting from the chemical conversion of the carbohydrates of the wood cellulose. The reaction is obtained by the hydrolysis of the cellulose with dilute sulphuric acid, followed by neutralization of the acid and evaporation of the resulting dilute sugar solution. The raw material is the wood residue from the forests or the mills; chiefly hogged wood, sawdust and chips. The latter items we have in abundance on the West Coast.

THE WOOD-SUGAR PROCESS

In the basic process, the two major products of the acid hydrolysis of wood cellulose are wood sugar and lignin. Other by-products are methanol, acetic acid and furfural. The wood sugar has three possibilities for further use; namely, the production of industrial alcohol, food yeasts, or molasses. The methods are briefly thus: for alcohol -- the sugar solution is heated, yeast added, fermentation takes place, the yeast is extracted, the liquor is distilled and you have ethyl alcohol. For food yeasts -- ammonia and other inorganic salts are fed into the sugar solution with air, the yeast grown, is recovered and dried. This material is rich in protein and B-complex vitamins and during the late war was a source of human food in some European countries. For molasses -- the sugar solution is concentrated to 50 percent solids; 1,000 pounds of sugar and 1,000 pounds of water making a ton of molasses. It is clear, slightly brown, bitter to the taste, and has distinct possibilities for use in animal feeds.

When the Springfield, Oregon, plant built by a World War II agency stopped the production of alcohol, it was thought it might be converted to the production of either food yeasts or molasses. Oregon is a heavy producer of livestock but like many similar grassland areas is short of the carbohydrate and protein nutrients that really grow the meat. The local livestock industry imports considerable quantities of the supplemental feeds, chiefly cane or beet molasses, to help finish the animals. The high cost of these items limit the extent of their use. While it is known that the wood-sugar molasses would be eaten by livestock, the local producers need to be shown and specific methods of use must be determined.

The U. S. Forest Products Laboratory at Madison, Wisconsin, initiated two pilot-plant projects, one at Madison and one at Wilson Dam, Tennessee, to provide molasses, to indicate the type of equipment needed and explore possible variations. These variations might then be incorporated in the Springfield plant. Molasses was produced on a small scale from Douglas fir wood and made available for research purposes in feeding tests undertaken in the Northwest at Montana State College, University of Idaho, Washington State College, and Oregon State College. The Oregon State tests were typical and were made with beef cattle, dairy cattle, sheep, hogs, and poultry. The Oregon Forest Products Laboratory assisted in the procurement of the molasses and the financing of the projects that were carried on by the Oregon State College Agricultural Experiment Station over a period of four years.

FEEDING TESTS

A brief summary of each of the several feeding projects at Oregon State College follows:

Dairy Cattle

(1) 3 lots of 4 two-year old dairy heifers -- 3 Holsteins and 1 Jersey in feed pens for 12 weeks - 1948.

Fed poor-quality chopped oats and vetch hay; later chopped grass hay, in quantities somewhat greater than normal consumption.

Lot 1 - approximately 2 pounds of barley ration per animal daily with the hay.

Lot 2 - approximately 3 pounds of wood-sugar molasses, diluted 2 to 3 times and sprinkled on hay.

Lot 3 - approximately 3 pounds cane molasses in same manner.

Results showed no appreciable difference in palatability between the two types of molasses, about the same quantity of material was eaten with average gains. There was a slight advantage in favor of the barley ration.

(2) 2 lots of 11 dairy cows in feed pens for 5 weeks - 1948.

*Presented at meeting of the Forest Products Research Society, Pacific Northwest Section, November 14, 1951, Longview, Washington.

Fed alfalfa harvested with a field chopper and ensiled in two silos, one with 3 percent wood-sugar molasses and the other with 3 percent cane molasses.

Lot 1 fed cane silage for 3 weeks and then wood-sugar silage for 2 weeks.

Lot 2 - just the reverse.

Results showed a slight preference for the wood-sugar molasses silage. There was no appreciable difference in feeding value as measured by milk production and weight changes.

(3) Similar silage study with yearling beef animals and the dairy herd at Astoria Experiment Station - 1950.

No discernible differences noted.

Sheep

(1) 3 lots of 21 lambs in feed pens for 60 days - 1949. Ammonia neutralized molasses.

Lot 1 - fed alfalfa hay and ration of barley and oats.

Lot 2 - 10 percent wood-sugar molasses substituted for grain.

Lot 3 - same except 20 percent molasses used.

Results showed much faster gain for 30 days with molasses rations, but the total gain averaged only slightly more than with grain. The test showed that ammonia neutralized wood-sugar molasses may be substituted for grain up to 20 percent with no ill effect on the palatability of meat. Sheep ate more roughage with molasses and would have eaten more.

(2) 3 lots of 12 lambs in feed pens for 60 days - 1950. Lime neutralized molasses.

Same as earlier test: one, control with alfalfa hay and mixed grain; one with 10 percent molasses substituted for grain, and one with 20 percent molasses substituted.

Results showed no ill effect up to 20 percent wood-sugar molasses; no effect on meat.

Lambs ate more of the coarse hay.

Swine

(1) 3 lots of 8 weaner pigs - average weight 77 pounds in feed pens for 75 days - 1949.

Lot 1 - fed ration of barley, tankage, and ground alfalfa.

Lot 2 - 15 percent of total ration was wood-sugar molasses substituted for barley.

Lot 3 - same as lot 2 except 5 percent of total ration was soybean oil substituted for tankage and barley.

Results: Molasses can be fed satisfactorily, slightly less gain with somewhat less cost. No appreciable difference between the two lots with molasses. No effect on themeator on the reproductive capacity of gilts. Earlier tests - 1948 - with molasses up to 30 percent were not too good.

Beef Cattle

(1) 2 lots of 5 beef heifers in feed pens for 53 days - 1949.

Lot 1 - fed native grass hay.

Lot 2 - fed 2.7 pounds of wood-sugar molasses supplement.

Results: Slightly higher winter gains in the lot fed molasses. No ill effect on cattle.

Laying Hens: Leghorn Pullets

(1) 4 lots of 24 pullets in wire-floored battery cages for 9 months - 1984-49.

Lot 1 - fed cereal grains (wheat, corn and oats).

Lot 2 - fed wood-sugar molasses for 7.5 percent of ration.

Lot 3 - fed wood-sugar molasses for 15 percent of ration.

Lot 4 - fed 7.5 percent molasses and 7.5 percent beet pulp in ration.

Results: Lot 2, on 7.5 percent molasses, showed an increase in egg production of 4 to 5 percent; partly due to greater food intake (average of 17 pounds more food). Lot 3 produced slightly less than Lot 1. Lot 4 failed to give any satisfactory results. Mortality was not affected adversely and the same was true for egg color at either level of molasses use.

(2) 4 lots of 36 pullets in wire-floored battery cages for 5 months - 1950.

Tests were the same as in previous study.

Results: Again the birds receiving 7.5 percent molasses excelled in egg production with an increased food intake. The 15 percent molasses again showed that this quantity approached the optimum amount that could be used. The inclusion of beet pulp appeared again to offset the benefits of molasses. There were no ill effects on the birds or on the color of the eggs.

(3) 3 lots of 50 pullets under study for 6 months of 1951-52, but project not completed.

One lot control; one with 7.5 percent molasses; and one with 15 percent molasses. Birds are on the floor; previous tests were with individually wire-floored battery cages.

Results of the 3 years' study:

Replacement of 7.5 percent grain ration with wood-sugar molasses brought an increase in egg production which more than offset increase in food intake.

Replacement of 15 percent of grain gave a ration that was readily consumed but did not justify the substitution, although a cost reduction is possible here.

Body weight and livability were not affected.

As molasses was added, the litter became somewhat stickier and eggs dirtier.

In summarizing the several tests, it is evident that the wood-sugar molasses made from Douglas fir can be substituted in the ration of the major livestock animals and poultry to a certain extent. The molasses is palatable, in fact it results in a greater consumption of rougher feeds in some cases, which would permit wider utilization of some types of feed. No ill effects were noticeable in the meat, the milk, or the eggs in the respective tests. The consensus is that this material could be as good, or better in some instances, than other feed supplements now being imported into the area. There should be a saving in cost as well as a means of utilizing woods and mill wastes, which would point to a new industry for the region. Similar studies at the other Experiment Stations bear out the above.

You might ask what the molasses will cost and how does it compare with competitive feeds? All of the answers are not known, but it can be estimated that the molasses might cost from $13.50 to $16.50 per ton without sales cost and overhead. This is assuming $2.00 for raw material, $3 to $4 for labor, $4.50 for power and $4 to $6 for plant costs. Those prices are expected to be competitive. Data are for plants erected at a cost of $300,000 to $400,000 to produce 50 tons a day, and a $100,000 plant to make 20 tons daily. Average yields for wood residues are roughly one ton of molasses per ton of wood.

It is hoped that with continued effort on the part of the many interested agencies, companies, and individuals, the end result will be more complete utilization of the wood material that our forests are capable of producing and which forms the basic economy of this region.

Poria Radiculosa, a Creosote-Tolerant Organism*

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INTRODUCTION

In an examination in 1947 of creosoted "pile bottoms"[1] that had been removed from service after about 10 years, the writer observed that the predominant organism in evidence was one whose stringlike rhizomorphs practically filled the rotted portions of these members so that armfuls could actually be obtained from just a few pieces. These rhizomorphs resembled white string when dead, but the living mycelium, which could be found by tracing the white threads into the moister sections of the wood, was sulphur yellow in appearance. The living yellow strands were found to be in contact with wood obviously containing residual creosote. Specimens of the mycelium were identified by Davidson as Poria luteofibrata, Baxter, which according to Lowe, is identical with Poria radiculosa, Peck.

TESTS OF THE ORGANISM

Tests reported by Richards and Addoms in 1947 (2) showed that Poria luteofibrata (Madison 699), was incapable of decaying longleaf pine sapwood containing as low as 2 pounds per cubic foot of a coal-tar creosote when tested for a period of five months, using four different testing techniques.

In the five years that have elapsed since the first observation of association of this organism with decay in creosoted wood, a number of other cases have been observed in creosoted poles, some of which had been replaced because of decay and others which were still standing in the lines, as well as in creosoted materials used for pile bottoms at wood preserving plants. In all cases, the wood has been southern pine During this period, samples have been submitted from time to time to various experts in an effort to clear up whether this organism really is an active agent causing decay in creosoted wood, but their tests using conventional laboratory methods failed to yield a positive answer. The discrepancy between the field observations and the laboratory tests led to the conclusion that the organism must be very slow in its action, as compared with most wood destroyers, and possibly could only survive in creosoted wood that had been weathered for a long period of time. This conclusion was based on the facts that all of the wood in which this form of decay has been observed, has been in service for at least 7 years and showed evidence of having been well weathered whereas the tests of Richards and Addoms, and others were made with fresh creosote which inhibited growth of the organism. Apparently, Duncan and Richards did not include this organism in their tests on weathered specimens which they reported in 1948 (1).

In November 1950, a test was set up by Hepting of The Division of Forest Pathology, U. S. Department of Agriculture, at Asheville, N.C. using this organism obtained directly from the decayed area of a pole that had been creosoted during 1943. Sound wood from the same pole was tested against cultures of this organism along with cultures of several pine-decaying fungi that are often used in tests of preservatively treated wood. Instead of running the test for the relatively short period that is customary, incubation was continued for 13 months. At the end of this time the weathered creosoted wood inoculated with Poria radiculosa showed about 20 percent weight loss whereas the pieces inoculated with the other fungi showed attack in only one instance. In this case the attack was very slight, having caused a weight loss of only about 5 percent.

A CASE HISTORY

The exact history of the pole from which these specimens were taken is not known for it is virtually impossible to trace a pole back to the original charge in which it was treated when such a long time has elapsed after treatment. It is known, however, that this pole was treated in a charge that obtained an average retention of 10 pounds per cubic foot of A.W.P.A. grade 1 creosote having a distillation residue above 355°C. of 18 to 22 percent and a specific gravity of the fraction distilling between 235° C. and 315° C. of 1.025 or more. Extraction of the residual creosote from the wood that was used in the above tests showed the presence of 3.3 pounds of preservative per cubic foot, with the following characteristics:

Specific gravity 38/38°C. 1.152

Distillation:

	Percent by weight
Up to 250° C.	2.7
250 to 355° C.	4.7
Residue above 355° C.	91.9
Distillation loss	0.7

[1]—Pile bottoms are creosoted poles that are laid on the ground to support untreated material such as poles and crossties during air seasoning.

*A contributed paper to the JOURNAL of the Forest Products Research Society.

The residual material extracted from the wood was almost solid and pitchlike with a rather high melting point, which is reflected by the very large percentage of residue above 355° C. shown in the foregoing analysis. This extract was typical of creosote that is found in treated wood after long exposure. Loss of lighter fractions and oxidation-polymerization reactions cause an increase in residue above 355° C. and also tend to impart glass-like qualities to the residue.

In Figure 1 are shown typical examples of mycelium of Poria radiculosa in weathered creosoted wood. Figure 2 shows fruiting bodies of the organism attached to portions of creosoted poles that are still sound. Generally, the organism is found working within from one inch of the surface to the center of the material.

This organism is considered important not because it produces early failure in many creosoted poles, since the percentage of creosoted poles that are early failures, as shown by the record of many companies, is very low; but the organism is considered important because of its association with decay of creosoted wood when this does occur. Because of this, it is considered highly important that Poria radiculosa be thoroughly re-examined as a test organism for the various laboratory methods for evaluating creosote, especially of weathered samples, because of its prevalence in instances of decay observed in the field. In this examination, the possibility that the particular strain of this organism that has been used heretofore in such tests, is different from that observed in the field, should not be overlooked.

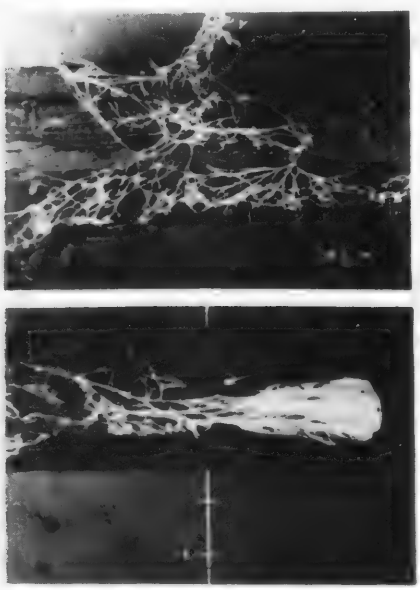

Fig. 1--Mycelium of Poria radiculosa in creosoted wood.

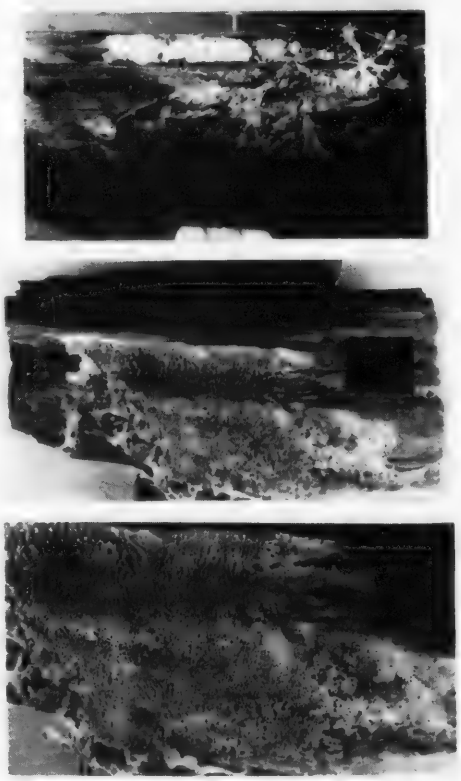

Fig. 2- Sporophores of Poria radiculosa on creosoted wood.

Photo at bottom is a closeup of sporophore shown at center.

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Coal Tar Creosote—Its Composition and How it Functions as a Wood Preservative

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WOOD PRESERVATION is an art. It is also a full-time undertaking requiring the best efforts and full energy of those who operate treating plants. The many problems associated with sales, purchases, plant operations, machinery, labor, variability of wood, and even the weather, leave little time for inquiring into the ramifications of the preservative beyond making certain that authentic preservatives complying with the standards of the industry are being purchased and used.

Occasions arise, however, when it would be helpful to have at hand basic information on the composition of the preservative and how it functions. Most treaters are familiar with the physical appearance of creosote, with the tests under which it is purchased and with its durable nature as attested by service records. Not all have as good an understanding of its composition and what makes it click. It is the purpose of this paper to present that part of the story of creosote.

Part of the difficulty of understanding creosote has been the need of a list of the compounds (chemicals) present in creosote. Such a list has been available for some time as part of the more inclusive list of compounds resulting from the carbonization of coal, but possibly there has been no occasion to list separately those compounds that occur in creosote. However, if one recalls that creosote is a bulk distillate of coal tar and that fractionation will show that it usually begins to distill at 175-200° C. and ends around 400-450° C., then a list of the compounds identified in that distilling range can be found by referring to pages 1357-1370 of the National Research Council Committee's book "Chemistry of Coal Utilization," which contains a list of the compounds identified from the carbonization of coal and arranged according to boiling point[1]. A list of the compounds in creosote as taken from that book will appear later as Table I. Contrary to expressed opinion, relatively few compounds are removed by the tar distiller, and we now turn to a review of the tar distillation industry so far as it applies to creosote.

*Presented at the Forest Products Research Society, Great Lakes Section, April 15, 1952, Grand Rapids, Michigan.

In the early days of tar distillation in this country, the main business of the tar distiller was making roofing pitch. This was made by distilling coal tar to a soft pitch -- the bulk distillate that came off during the distillation was the creosote desired by the wood preserving industry, except that there was too much volatile or "front end" material -- often too much naphthalene.

To accommodate these lighter, less permanent, creosotes, specifications for grade 2 and grade 3 creosotes were developed. According to Odell[2], the American Wood Preservers Association "Handbook on Wood Preservation," (Baltimore, 1916, 73 pp.) shows the following as the American Railway Engineering Association specification for creosote oil at that time:

		Grades		
		1	2	3
Distillation:[a]				
Below 210° C., not over	%	5	8	10
Below 235° C., not over	%	25	35	40
Residue above 355° C. must be soft and greater than	%	5	5	5
Water, not over	%	3	3	3
Specific gravity at 38° C., not less than		1.03	1.03	1.025

[a]Distillation results are calculated on the basis of dry oil when distilled by the method adopted by the American Railway Engineering Association in an 8-ounce asbestos-covered retort, with standard thermometer and bulb one-half inch above the surface of the oil. Percent here means percent by weight.

To get away from the grade 2 and grade 3 specifications and to make the more desirable (more permanent) grade 1 creosote, a distillation cut was taken at the beginning of the tar distillation and this material kept out of creosote. This cut contained the more volatile material including some of the naphthalene (boiling at 218° C.) with the result that the creosote then complied with the percentages of distillate permitted by the grade 1 specification at 210 and at 235° C.

The cut taken at the front end had as little distilling above 235° C. as possible, and it found sale as "insecticide oil" for the manufacture of sheep and cattle dip and for the manufacture of so-called coal tar disinfectants.

Today the tar distiller follows approximately the same procedure. True, the tar business has been extended to include harder pitches and arsenical dips have replaced "insecticide oil" dips. A new market for "insecticide oil" arrived with the active commercialization of Bakelite resins. This market was made to order for the tar distiller for it created a continuing market for the low boiling tar acids (phenol, the 3 isomeric cresols and the 6 isomeric xylenols) contained in "insecticide oil". The "insecticide oil" cut is still taken but now it is washed to remove the tar acids which are worked up into finished phenol, cresols and xylenols and the remainder is chilled or distilled to remove naphthalene and finally an acid wash is sometimes used to remove tar bases (quinoline). The remaining oil is added to creosote if sufficiently high boiling. Only tars rich in acids and naphthalene are worked up and removal is usually "commercial" rather than complete. The practice varies somewhat from company to company and from plant to plant.

Tar distillers purchase "coke plant phenolate" and "coke plant bases" from the by-product coke plants where they are recovered independently of the tar and work them up for sale. The former yield mostly phenol and cresols, and the latter, pyridine and picolines. Coumarone and indene used for resin manufacture are obtained from the low boiling fraction as will be seen from their boiling points.

Anthracene solids are produced when making AWPA and AREA specification Brush and Spray oil. This is not an extensive operation. During World War I, anthracene cake (approximately 35 percent anthracene with the balance mostly carbazole and phenanthrene) was produced and sold to dye manufacturers to make anthraquinone which is the basis of vat-type dyes. Although the dyestuff industry has continued to manufacture these dyes, the development of a cheap method for the manufacture of phthalic anhydride from naphthalene in 1918 opened the way to a synthesis of anthraquinone which has completely replaced anthraquinone from anthracene, and it is safe to say that there has not been any extensive production of anthracene in the United States in the last 25 years, and as a consequence, this material is no longer recovered.

Aside from the compounds discussed above, reference to the annual reports of the Tariff Commission "Synthetic Organic Chemicals"(8) will show no other chemicals from tar boiling in the creosote range are removed or sold in amounts worth reporting. Basically then, in the distillation of tar, the producer first takes a low boiling cut which gives him certain chemicals (coumarone, indene, phenol, the cresols, the xylenols, quinoline and naphthalene), then a wide boiling fraction which is his main creosote production and from which nothing is extracted and there remains behind, coal tar pitch. All compounds that are removed are in the low boiling range.

We are now ready to establish the compounds in commercial coal tar creosote. For convenient reference Table I is set up to show (a) the list of compounds in the 175-450° C. distilling range, (b) the compounds invariably recovered in creosote production, (c) the compounds frequently recovered, and finally (d) for comparison, a column showing what the practice was 30 years ago. A number of other compounds are believed present in small amounts but they have not been positively identified.

The total number of compounds shown in Table I is 162. This marks creosote as an impressive material from the standpoint of composition. Although numbered consecutively for purposes of information and reference, it is not intended to convey that all are present in equal proportions or that the proportions are the same in all samples of creosote. Some twenty-five to thirty compounds account for nearly half the volume, which means that a number are present in fairly small percentages. More detailed information appears on pages 1325-1327 of the National Research Council book (1) and on pages 16-23 of Bulletin 412 of the U. S. Bureau of Mines "Composition of Coal Tar and Light Oil" (7). Table I also shows that the boiling points of the compounds listed as "Frequently recovered" are in line with conformity to specification and that such recovery does not constitute any new development.

Our understanding of creosote has now advanced to the point where we have a specific list of components. It remains to determine whether these compounds are toxic to fungi or whether the effectiveness of creosote stems from a single compound or small group of compounds. The names of the more abundant ingredients of creosote have been known for some time and, while a goodly number of the less plentiful remain to be tested, much work has already been done and investigators have developed substantial evidence to show that each individual component in creosote is effective toward wood destroying fungi (3). Not all of the compounds are equally effective nor is any one compound equally effective against all strains of fungi. Schulze and Becker (4) brought these points out clearly in some work published in 1948. A table giving some of their data is reproduced below as Table II and shows the results of tests of 27 of the individual components of creosote, along with results on 9 fractions. Note that the 27 compounds cover almost the whole of the dis-

tilling range of creosote and that three fungi were used -- Coniophora cerebella, Poria vaporaria and Lentinus lepidius.

It is apparent from a study of Table I and Table II that the effectiveness of creosote as a wood preservative is due to the multiplicity of compounds present and not to the magic influence of any single compound or small group of compounds.

But the story does not end here, for Bateman and Henningsen (5) at the Forest Products Laboratory pointed out that an exact picture of the toxicity of creosote is not obtained by separating it into its individual components and testing each separately. Using growth curves they showed that while a single pure component of creosote, acenaphthene for example, has a definite toxicity toward a fungus, and while a second pure component, say diphenyl, has its own definite toxicity toward that fungus that when the two pure compounds are mixed together and the mixture tested, the effect on the fungus is far greater than that of either compound alone. The large number of compounds in creosote thus takes on added significance and the implications of the Bateman and Henningsen findings are enormous.

In view of what has just been established about the composition of creosote and how it functions, it is not surprising that outstanding service records of creosoted structures are commonplace in the wood preserving industry and that fungi have been unable to accommodate themselves to this preservative even over long periods of time or to develop a resistance to it as might have happened to a single toxic.

When it comes to methods of analysis, the profusion of compounds in creosote does have a seeming disadvantage. It is logical, however, not to name the various chemical compounds or to designate the proportions of each that the oil should contain (6) but rather to base the specification on the distilling range. This assures that the creosote will have a normal distillation range falling within the variations and distillation patterns of those creosotes on which the service records are based. It also assures the presence of a large number of compounds. The testing of creosoted wood in the field in a simple and easy matter.

SUMMARY

Coal tar creosote is shown to be an impressive mixture containing upwards of approximately 160 separate and distinct chemical compounds identifiable as to name, chemical structure and boiling point. A list of the more prominent compounds embracing the greater part of the distilling range of creosote when tested individually in wood were all found toxic to fungi. The presence of the large number of compounds (and proper permanence) is assured by the wide distilling range which is a time-proven part of the specification.

When mixed together, the compounds are much more effective than when tested separately.

Comparison of creosote production practice now and 30 years ago shows approximately the same compounds recovered by the tar distiller then as now. All fall within the low boiling range.

It is therefore the great multiplicity of compounds in creosote, their individual effectiveness toward fungi, plus their enhanced effectiveness in admixture with one another and their permanence that is responsible for the performance of creosote.

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(7) Fisher, C. H., Composition of Coal Tar and Light Oil, Bulletin 412, U. S. Bureau of Mines, Govt. Print. Office, 1938.

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TABLE I

COMPOUNDS PRESENT IN COAL TAR CREOSOTE

Compounds in straight run creosote distilling 175/450 deg. C arranged according to boiling point. Taken from pp. 1357-1370 of National Research Council Committees book "Chemistry of Coal Utilisation" (John Wiley and Sons, Inc., New York, 1945.)

	Compound	Formula	Boil.Pt.
1.	Coumarone	C_8H_6O	173-175
2.	1,2,3-Trimethylbensene	C_9H_{12}	176.1
3.	Cymene	$C_{10}H_{14}$	177
4.	Hydrindene	C_9H_{10}	178
5.	Phenol	C_6H_6O	181
6.	Indene	C_9H_8	182
7.	Aniline	C_6H_7N	184
8.	3,4-Dimethylethylbensene	$C_{10}H_{14}$	189
9.	Ammonium thiocyanate	NH_4SCN	d.190
10.	6-Methylcoumarone	C_9H_8O	190-191
11.	o-Cresol	C_7H_8O	190-191
12.	Bensonitrile	C_7H_5N	191
13.	3or5-Methylcoumarone	C_9H_8O	195-196
14.	n-Undecane	$C_{11}H_{24}$	195.8
15.	Durene (1,2,4,5-tetramethylbensene	$C_{10}H_{14}$	196
16.	4-Methylcoumarone	C_9H_8O	197-199
17.	Isodurene (1,2,3,5-tetramethylbensene)	$C_{10}H_{14}$	198
18.	p-Toluidine	C_7H_9N	200.4
19.	o-Toluidine	C_7H_9N	200.7
20.	p-Cresol	C_7H_8O	201
21.	Acetophenone	C_8H_8O	202
22.	m-Cresol	C_7H_8O	202
23.	m-Toluidine	C_7H_9N	203.3
24.	4-Methylindene	$C_{10}H_{10}$	205
25.	Tetrahydronaphthalene	$C_{10}H_{12}$	206.8
26.	2,4-Xylenol	$C_8H_{10}O$	209
27.	2,6-Xylenol	$C_8H_{10}O$	211.2
28.	2,5-Xylenol	$C_8H_{10}O$	211.5
29.	2,4-Xylidine	$C_8H_{11}N$	212
30.	m-Ethylphenol	$C_8H_{10}O$	214
31.	2,5-Xylidine	$C_8H_{11}N$	215
32.	p-Ethylphenol	$C_8H_{10}O$	218
33.	Naphthalene	$C_{10}H_8$	218
34.	2,3-Xylenol	$C_8H_{10}O$	218
35.	3,5-Xylenol	$C_8H_{10}O$	219.5
36.	3,5-Xylidine	$C_8H_{11}N$	220-221
37.	3,6-Dimethylcoumarone	$C_{10}H_{10}O$	220-222
38.	4,5-Dimethylcoumarone	$C_{10}H_{10}O$	220-222
39.	4,6-Dimethylcoumarone	$C_{10}H_{10}O$	220-222
40.	Thionaphthene	C_8H_6S	222
41.	2,3-Xylidine	$C_8H_{11}N$	223
42.	3,4-Xylenol	$C_8H_{10}O$	225
43.	Dimethylindene	$C_{11}H_{12}$	225-230
44.	Pseudocumenol (2,4,5-trimethylphenol)	$C_9H_{12}O$	232
45.	3-Ethyl-5-methylphenol	$C_9H_{12}O$	232.5-234.5
46.	2,3,4,5-Tetramethylpyridine	$C_9H_{13}N$	233
47.	Isopseudocumenol (2,3,5-trimethylphenol)	$C_9H_{12}O$	233
48.	Quinoline (leucoline)	C_9H_7N	238
49.	7-Hydroxycoumarone	$C_8H_6O_2$	240
50.	Methylthionaphthene	C_9H_8S	240-245
51.	2-Methylnaphthalene	$C_{11}H_{10}$	241.14
52.	Isoquinoline	C_9H_7N	243.25
53.	1-Methylnaphthalene	$C_{11}H_{10}$	244.78
54.	4-Hydroxyhydrindene	$C_9H_{10}O$	245
55.	2-Methylquinoline	$C_{10}H_9N$	247.60
56.	8-Methylquinoline	$C_{10}H_9N$	247.75
57.	3,4,5-Trimethylphenol	$C_9H_{12}O$	248
58.	Durenol (2,3,5,6-tetramethylphenol)	$C_{10}H_{14}O$	248
59.	Bensoic acid	$C_7H_6O_2$	249
60.	5-Hydroxyhydrindene	$C_9H_{10}O$	251
61.	2-Ethylnaphthalene	$C_{12}H_{12}$	252
62.	3-Methylisoquinoline	$C_{10}H_9N$	252.25
63.	Indole	C_8H_7N	253
64.	Diphenyl	$C_{12}H_{10}$	255.2
65.	1-Methylisoquinoline	$C_{10}H_9N$	255.25
66.	2,8-Dimethylquinoline	$C_{11}H_{11}N$	255.25
67.	7-Methylquinoline	$C_{10}H_9N$	257.60
68.	6-Methylquinoline	$C_{10}H_9N$	258.60
69.	3-Methylquinoline	$C_{10}H_9N$	259.55
70.	2,6-Dimethylnaphthalene	$C_{12}H_{12}$	260.5
71.	2,7-Dimethylnaphthalene	$C_{12}H_{12}$	262
72.	1,7-Dimethylnaphthalene	$C_{12}H_{12}$	262
73.	1,3-Dimethylisoquinoline	$C_{11}H_{11}N$	262.40
74.	1,6-Dimethylnaphthalene	$C_{12}H_{12}$	262.5
75.	5-Methylquinoline	$C_{10}H_9N$	262.70
76.	4-Methylquinoline	$C_{10}H_9N$	264.20
77.	5-or 7-Methylisoquinoline (probable)	$C_{10}H_9N$	264.90
78.	3-Methylindole (skatole)	C_9H_9N	265
79.	1,5-Dimethylnaphthalene	$C_{12}H_{12}$	265-265.5
80.	6-Methylisoquinoline (probable)	$C_{10}H_9N$	265.50
81.	7-Methylindole	C_9H_9N	266
82.	2,3-Dimethylnaphthalene	$C_{12}H_{12}$	266
83.	1,2-Dimethylnaphthalene	$C_{12}H_{12}$	266-267
84.	4-Methylindole	C_9H_9N	267
85.	5-Methylindole	C_9H_9N	267
86.	3-Methyldiphenyl	$C_{13}H_{12}$	269
87.	5,8-Dimethylquinoline	$C_{11}H_{11}N$	> 270
88.	4-Methyldiphenyl	$C_{13}H_{12}$	271
89.	2-Methylindole	C_9H_9N	271-272
90.	o-Phenylphenol	$C_{12}H_{10}O$	275

PRESENT DAY PRACTICE

Compounds **invariably** removed during production of commercial creosote

-none-

Compounds **frequently** removed during production of commercial creosote

Compound	Boil.Pt.
Phenol	181
o-Cresol	191
p-Cresol	201
m-Cresol	202
2,4-Xylenol	209
2,6-Xylenol	211.2
2,5-Xylenol	211.5
Naphthalene	218
2,3-Xylenol	218
3,5-Xylenol	219.5
3,4-Xylenol	225
Quinoline	238
COUMARONE	173-175
INDENE	182

Compounds frequently removed 30 years ago. Reference: U.S.Bureau Mines Tech. Paper 268 Prep. and Uses of Tar and its Simple Derivatives W.W. O'Dell, Govt. Print. Office, 1922

Insecticide Oil mostly phenol, cresols, xylenols, naphthalene and tar bases.

At times - Anthracene cake. (Anthracene phenanthrene and carbazole)

91.	1,3,7-Trimethylnaphthalene	$C_{13}H_{14}$	280
92.	a-Naphthol	$C_{10}H_8O$	280
93.	Acenaphthene	$C_{12}H_{10}$	280.7
94.	a-Naphthofurane	$C_{12}H_8O$	282-284
95.	B-Naphthofurane	$C_{12}H_8O$	284-286
96.	2,3,5-Trimethylnaphthalene	$C_{13}H_{14}$	285
97.	2,3,6-Trimethylnaphthalene	$C_{13}H_{14}$	286.0
98.	B-Naphthol	$C_{10}H_8O$	286
99.	Diphenylene oxide	$C_{12}H_8O$	287
100.	2,4,6-Trimethylquinoline	$C_{12}H_{13}N$	288
101.	3,4-Dimethyldiphenyl	$C_{14}H_{14}$	289
102.	4,4'-Dimethyldiphenyl	$C_{14}H_{14}$	292
103.	g-Diphenylenemethane	$C_{13}H_{10}$	295
104.	4,5-Benzindan	$C_{13}H_{12}$	295
105.	1-Naphthonitrile (1-cyano-naphthalene)	$C_{11}H_7N$	297
106.	1-Methyldiphenylene oxide	$C_{13}H_{10}O$	298
107.	Fluorene	$C_{13}H_{10}$	298
108.	Hydroacridine	$C_{13}H_{11}N$	d.300
109.	1-Naphthylamine	$C_{10}H_9N$	301
110.	2-Methyldiphenylene oxide	$C_{13}H_{10}O$	303-304
111.	2-Naphthonitrile (2-cyano-naphthalene	$C_{11}H_7N$	304
112.	2-Naphthylamine	$C_{10}H_9N$	306
113.	Paraffin (octadecane)	$C_{18}H_{38}$	308
114.	Heneicosane	$C_{21}H_{44}$	310
115.	2-Methylfluorene	$C_{14}H_{12}$	318
116.	3-Methylfluorene	$C_{14}H_{12}$	318
117.	p-Phenylphenol	$C_{12}H_{10}O$	319
118.	Tricosane	$C_{23}H_{48}$	320.7
119.	Tetracosane	$C_{24}H_{50}$	324.1
120.	Pentacosane	$C_{25}H_{52}$	325
121.	Docosane	$C_{22}H_{46}$	327
122.	Nonadecane	$C_{19}H_{40}$	328
123.	Hexacosane	$C_{26}H_{54}$	330
124.	Heptacosane	$C_{27}H_{56}$	330
125.	Octacosane	$C_{28}H_{58}$	330
126.	Diphenylene sulfide	$C_{12}H_8S$	332
127.	Phenanthrene	$C_{14}H_{10}$	340
128.	Tetramethylbiphenol	$C_{16}H_{18}O_2$	341
129.	Anthracene	$C_{14}H_{10}$	342.3
130.	Acridine	$C_{13}H_9N$	346
131.	2-Hydroxybiphenylene oxide	$C_{12}H_8O_2$	348
132.	Phenanthridine	$C_{13}H_9N$	349
133.	3-Methylphenanthrene	$C_{15}H_{12}$	350
134.	Carbazole	$C_{12}H_9N$	352
135.	2-Hydroxyfluorene	$C_{13}H_{10}O$	ca. 352
136.	4,5-Phenanthrylenemethane	$C_{15}H_{10}$	353
137.	9-Methylphenanthrene	$C_{15}H_{12}$	354-355
138.	1-Methylphenanthrene	$C_{15}H_{12}$	354-355
139.	2-Phenylnaphthalene	$C_{16}H_{12}$	357-358
140.	Hydroxyanthracene	$C_{14}H_{10}O$	d. 360
141.	Naphthacene	$C_{18}H_{12}$	360
142.	2-Methylanthracene	$C_{15}H_{12}$	360
143.	2,7-Dimethylanthracene	$C_{16}H_{14}$	360
144.	2-Methylcarbazole	$C_{13}H_{11}N$	363
145.	1,2,3,4-Tetrahydrofluor-anthene	$C_{16}H_{14}$	363-365
146.	Truxene	$(C_9H_6)_2$ or $(C_9H_6)_3$	s.364-365
147.	3-Methylcarbazole	$C_{13}H_{11}N$	365
148.	Fluoranthene	$C_{16}H_{10}$	382
149.	2,3,5,6-Dibenzocoumarone	$C_{16}H_{10}O$	392-397
150.	Pyrene	$C_{16}H_{10}$	393
151.	1,9-Benzoxanthene	$C_{16}H_{10}O$	395
152.	2-Hydroxyphenanthrene (2-phenanthrol)	$C_{14}H_{10}O$	396
153.	Retene (8-methyl-2-isopropylphenanthrene	$C_{18}H_{18}$	396.8
154.	1,2-Benzofluorene (naphtho-fluorene)	$C_{17}H_{12}$	413
155.	2,3-Benzofluorene (isonaphthofluorene)	$C_{17}H_{12}$	415
156.	Naphtho-2',3'-1,2-anthracene	$C_{22}H_{14}$	424
157.	1,2-Benzonaphthacene	$C_{22}H_{14}$	425
158.	Phenanthridone	$C_{13}H_9NO$	435
159.	Dibenzothionaphthene	$C_{16}H_{10}S$	ca. 440
160.	Sulfur	S	444.6
161.	Chrysene	$C_{18}H_{12}$	448.5
162.	Triphenylene	$C_{18}H_{12}$	450

TABLE II

PRESERVATIVE VALUE OF CREOSOTE COMPOUNDS AND CREOSOTE FRACTIONS

(European agar-wood block method)

Reference: Schulze and Becker (4)

Material Tested	Chemical Formula	Type[1]	Boiling Point °C	Melting Point °C	Density	Preservative Value Against Fungi Limit Values—Lb. per Cu. Ft. *Con. cerebella*	*Poria vaporaria*	*Len. lepideus*
Whole Creosote	--------	----	---	-------	----------	0.32-0.42	0.35-0.41	1.53-1.83
Fraction—180°-200° C	--------	----	---	-------	----------	0.34-0.49	0.52-0.84	0.53-0.78
200°-220° C	--------	----	---	-------	----------	0.24-0.38	0.38-0.50	0.50-0.81
220°-240° C	--------	----	---	-------	----------	0.51-0.79	0.40-0.55	0.81-1.10
240°-260° C	--------	----	---	-------	----------	0.71-0.98	0.51-0.81	1.18-1.81
260°-280° C	--------	----	---	-------	----------	0.38-0.52	0.55-0.82	1.28-2.00
280°-300° C	--------	----	---	-------	----------	0.24-0.36	0.42-0.55	1.37-2.00
300°-330° C	--------	----	---	-------	----------	0.24-0.38	0.77-1.07	1.28-1.91
330°-360° C	--------	----	---	-------	----------	0.49-0.75	1.10-1.28	0.71-0.97
Residue	--------	----	---	-------	----------	----------	4.97-10.1	4.91-10.1
Phenol	C_6H_6O	TA	181	41	1.005-45°	0.29-0.40	1.69-2.15	<0.008
Aniline	C_6H_7N	TB	184	—6	1.02	6.1-9.9	2.93-6.10	----------
Benzonitrile	C_7H_5N	NN	191	—13	1.005	0.76-0.80	1.93-3.50	1.93-3.50
Cresol—Ortho	C_7H_8O	TA	191	31	1.048)			
Cresol—Meta	C_7H_8O	TA	202	11	1.034)	0.56-0.84	0.32-0.47	0.47-0.62
Cresol—Para	C_7H_8O	TA	202	34	1.035)			
Acetophenone	C_8H_8O	NO	202	20	1.030	1.10-1.40	0.80-1.10	1.34-2.80
Naphthalene	$C_{10}H_8$	H	218	80	1.17	0.19-0.26	0.27-0.43	1.28-2.50
Thionaphthene	C_8H_6S	S	227	32	1.148-36°	0.21-0.29	0.45-0.69	0.51-0.87
Quinoline	C_9H_7N	TB	238	—15	1.093	0.29-0.40	2.81-5.60	0.57-0.80
Isoquinoline	C_9H_7N	TB	242	25	1.098	0.47-0.78	0.38-0.47	0.80-1.07
Methylnaphthalene (beta)	$C_{11}H_{10}$	H	242	34	1.0297	0.43-0.55	0.57-0.92	1.15-1.37
Methylnaphthalene (alpha)	$C_{11}H_{10}$	H	248	—22	1.0007	0.32-0.47	0.85-1.28	0.60-1.10
Quinaldine	$C_{10}H_9N$	TB	248	—2	1.059	0.55-0.85	2.81-4.68	0.97-1.15
Diphenyl	$C_{12}H_{10}$	H	255	70	----------	0.58-0.86	>6.6	>6.5
2, 6-Dimethylnaphthalene	$C_{12}H_{12}$	H	262	110-111	1.0087	3.62-4.76	>4.80	>4.87
Acenaphthene	$C_{12}H_{10}$	H	278	95	1.06	1.31-1.94	2.50-4.74	>1.92
Alpha-naphthol	$C_{10}H_8O$	TA	280	96	1.224	0.75-1.01	0.09-0.14	0.36-0.49
Beta-naphthol	$C_{10}H_8O$	TA	286	123	1.217	0.26-0.36	0.11-1.82	0.24-0.37
Diphenylene-oxide	$C_{12}H_8O$	NO	287	85	----------	1.41-2.15	2.87-5.87	>5.87
Fluorene	$C_{13}H_{10}$	H	294	115	----------	0.94-1.37	2.15-3.13	>7.99
Phenanthrene	$C_{14}H_{10}$	H	340	100	1.063-101°	0.48-0.99	2.43-3.51	4.61-8.74
Anthracene	$C_{14}H_{10}$	H	340	217	1.242	>0.87	>0.87	>0.87
Acridine	$C_{13}H_9N$	TB	346	110	----------	----------	<0.75	<0.76
Carbazole	$C_{12}H_9N$	TB	352	238	----------	>2.18	>4.02	>4.02
Pyrene	$C_{16}H_{10}$	H	393	149-150	----------	3.93-5.42	>5.90	3.00-4.06
Fluoranthene	$C_{16}H_{10}$	H	382	109	----------	>5.92	>5.36	>5.36

>More than.
<Less than.

[1]TA—Tar acid, TB—Tar base (amine), NN—Neutral nitrogen compound, NO—Neutral oxygen compound, H—Neutral hydrocarbon, S—Sulphur compound.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Treatability of Shortleaf Pine by the Cold Soaking Method*

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TREATING SOUTHERN YELLOW PINE POSTS by cold soaking may not be as simple as it first appeared. While it is fairly easy to get satisfactory treatment, controlling absorption and penetration is much more difficult in this process than in either pressure or hot-and-cold-bath treating. The possibility of developing cold-soak treating schedules becomes more and more remote as evidence of wide variation in treating times and results continue to pile up. Many contributing variables are quickly recognized but their real importance and specific effects are not fully known.

In order to pin down some of these unknowns and expose them as real or imaginary, we ran a series of treatability tests on sound shortleaf pine posts.[1] The controlled variables were post diameter, growth rate, temperature of wood and preservative, and rate of treatment. Other factors that affect absorption and penetration were noted but not analyzed. Such things as moisture content, weathered surface, insect holes, and infection by decay, stain, and mold organisms warrant further study.

The results of our tests indicate a very definite relationship between post size and treating time, but just the opposite to that generally assumed. As post size decreases the ratio of surface area to volume increases. This would naturally lead one to expect that small posts would take up preservative faster than larger ones. Actually, our tests showed that posts four inches in diameter will treat in half the time required for three-inch posts. Five-inch posts will treat faster than four-inch ones.

We found no significant relationship between growth rate and treating time. As temperature of the preservative increased, treating time decreased. There seemed to be no advantage in heating the wood to temperature slightly above the temperature of the preservative. Copper naphthenate and pentachlorophenol in No. 2 fuel oil solutions were both absorbed at about the same rate. Penetration was excellent, and we found that oil soluble preservatives continue to move inward after the wood is taken out of the treating solutions.

METHOD

These tests were designed to determine the effect of diameter, growth rate, and temperature on the treatability of shortleaf pine by cold soaking. The oil soluble preservatives used were pentachlorophenol and copper naphthenate. The standard of satisfactory treatment was six pounds of preservative per cubic foot of wood. Penetration was measured immediately following treatment and again one week later.

We prepared 324 test sections from 54 six-foot shortleaf pine posts. All posts had been cut from the same plantation, peeled, and stacked for seasoning approximately three months before the tests began (Fig. 1). All were free from visible signs of rot; they were uniform and straight and had no large knots or checks.

Each of three midpoint post diameters (3, 4, and 5 inches) and each growth rate class (5, 10, and 15 rings per outer inch) was represented by six posts. Each post was cut into six sections 11.5 inches long. These were arranged in test units of two samples each according to the pattern shown in Table 1. This meant that each post was represented in the various temperature and preservative groupings by end-matched sections.

As the diameter and surface condition of each section were recorded, the ends were coated with shellac to prevent end penetration of the preservative during treatment. Actual treating began when the moisture content of all post sections reached 20 percent or less.

Preservative concentrates were carefully mixed with No. 2 fuel oil. The copper naphthenate solution contained 0.5 percent copper metal by weight and the pentachlorophenol solution contained 5 percent pentachlorophenol by weight.

Preservative temperatures (Table 1) were kept constant throughout each treating period. Test

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*A contributed paper to the JOURNAL of the Forest Products Research Society.

[1]Tests were conducted by Elmer A. Snow, TVA Forester, under the direction of W. N. Darwin, Chief, Forest Utilization Section, Forestry Investigations Branch, Division of Forestry Relations, Tennessee Valley Authority, Norris, Tennessee. Data were analyzed by Sara M. Potts, Statistical Clerk, under the direction of W. H. Cummings, Chief, Forest Management Section.

Fig. 1--Posts were seasoned for three months in stacks under cover.

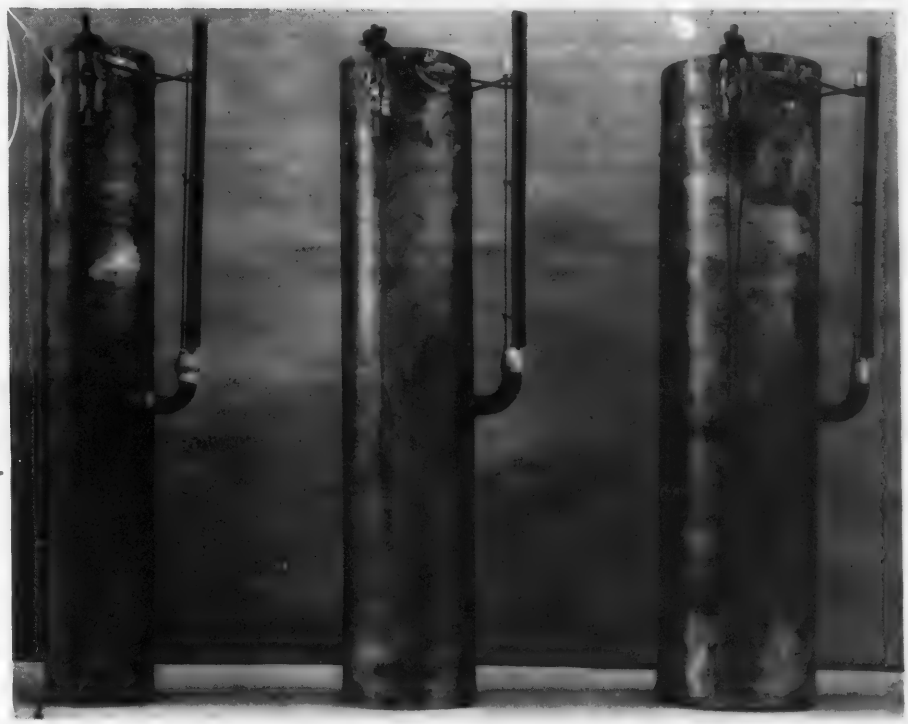

Fig. 2--Special treating cylinders were used. Cylinder diameters were four, five, and six inches.

Fig. 3--Pentration data were obtained immediately after treatment from increment borings and, one week later, from split surfaces.

sections were put in an oven or exposed to atmospheric temperatures of the proper range for at least six hours to make sure they were at the proper temperature. Weight, moisture content, and temperature were recorded for each test sample just before it was immersed in the preservative.

All treating was done in specially constructed treating cylinders, 24 inches high and 4, 5, and 6 inches in diameter (Fig. 2). Each was equipped with a glass tube gauge to measure liquid displacement and absorption, and a device on top to keep the test block submerged.

Volume of each sample was determined by displacement immediately after immersion in the treating cylinder. The drop in preservative level necessary to give a treatment of six pounds per cubic foot of wood was calculated and the sample was removed when that level had been reached. None were soaked longer that 72 hours. The treated sample was weighed after the unabsorbed treating solution had drained off. Difference between the initial and final weights gave the weight of the preservative absorbed.

Penetration was checked immediately after treatment with an increment borer. After a storage period of one week each test sample was split into quarters and penetration was again measured. The quarter that showed next to poorest penetration was used for record purposes (Fig. 3).

RESULTS

Data accumulated in these tests are too extensive to publish but they are available on request. Some of the significant facts are summarized in Tables 2 and 3 and Figs. 4 and 5.

In summary, these are the conclusions we reached:

1. Treating time varies inversely with post diameter. Four-inch posts treat in half the time required for three-inch posts. Five- inch posts require 13 percent less time than the four-inch ones.

2. As the temperature of the preservative increases, average treating time decreases. Raising the temperature from 70° F. to 90° F. resulted in a greater reduction in treating time than raising it from 50° F. to 70° F.

3. Growth rate, as measured by annual ring count, has no significant effect on treating time.

4. Raising wood temperatures 10° F. to 30° F. above the preservative temperature produces no significant results.

5. There is no significant difference in treating time efficiency between fuel oil solutions of copper naphthenate and pentachlorophenol.

6. Average penetration of these two preservatives into shortleaf pine is excellent. Only six sections (1.8 percent) showed less than 0.5 of an inch penetration; 188 sections (58 percent) showed almost complete penetration.

7. Differences in penetration as measured on increment borings and on split surfaces a week later are significant for all diameter classes. The preservative continued to move inward an average of 0.2 to 0.3 of an inch during the seven days between penetration tests.

8. The effect of moisture content on treating time could not be analyzed because of the narrow range of moisture encountered. All blocks but one were below 20 percent moisture content; most of them were between 15 and 20 percent.

Cold soaking has often been described as the most simple method of effectively treating posts, poles, lumber, and timbers. This is certainly true if you consider equipment and operating costs only. But on the basis of our treatability tests on shortleaf pine, cold soaking is actually one of the most difficult methods by which to secure uniformly satisfactory and effective treatment.

Uniformity of treatment within a given batch of posts is practically impossible by cold soaking. However, this variability can be reduced to a minimum by making up loads carefully and maintaining continuous control during treatment. Sound posts should be sorted into groups of nearly uniform diameter and each size should be treated separately. Average treating time for three-inch posts can be expected to be twice that for four-inch posts.

But knowing this still does not permit adoption of fixed time schedules. Even though loads are carefully made up, operating on a time schedule is apt to result in serious irregularities between batches and within batches. For this reason continuous control must be exercised. The total wood volume of each batch should be computed. Then the amount or weight of preservative required to treat that batch should be determined. Posts should not be removed from the treating tank until the calculated amount of preservative has been absorbed or until the rate of absorption has slowed to the point where additional soaking is impractical.

While treating time is reduced by increasing preservative temperature, this does not mean that treating cannot be done during the winter months typical of the Tennessee Valley. It takes

longer, but you can get satisfactory results right through the winter.

Another point to remember is that penetration of the preservative apparently continues for some time after the soaking process. How long is not known for sure, but our tests show that a week is not too long to wait for final measurement.

Table 1 - Organizational Pattern of Treatability Tests

Temperature of Preservative	Temperature of Atmosphere and of Wood	Preservative	
		CuN	Penta
Degrees F	Degrees F	Test Units	
50	60	(1-3)* (2-4)	(1-4) (2-3)
	70	(5-5) (6-6)	(5-6) (6-5)
	80	(3-2) (4-1)	(3-1) (4-2)
70	80	(3-3) (4-4)	(3-4) (4-3)
	90	(5-2) (6-1)	(5-1) (6-2)
	100	(1-5) (2-6)	(1-6) (2-5)
90	100	(1-2) (2-1)	(1-1) (2-2)
	110	(3-5) (4-6)	(3-6) (4-5)
	120	(5-4) (6-3)	(5-3) (6-4)

* Test Unit composed of Post 1 - Section 3, and Post 2 - Section 4. This arrangement was followed for each diameter and ring class combination.

Table 2 - Movement of Preservative During First Seven Days After Treatment. Average Rate of Treatment - 6 Pounds Per Cubic Foot of Wood

Diameter Class (Inches)	Penetration (Inches)				Inward Movement (Inches)
	Increment Borings		Split Surfaces		
	Range	Average	Range	Average	Average
3 1/	0.3 - 1.8 2/	1.2	0.3 - 2.0	1.4	0.2
4	0.2 - 2.4	1.5	0.3 - 2.7	1.7	0.2
5	0.6 - 2.6	1.8	0.6 - 2.9	2.1	0.3

1/ Post mid-diameter

2/ Based on individual test section measurements

Figure 4 - Effect of Post Diameter on Average Treating Time. Average Rate of Treatment - 6 Pounds of Preservative per Cubic Foot of Wood.

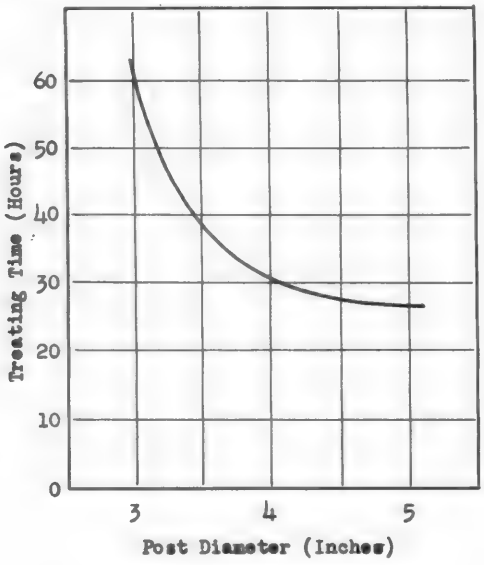

Figure 5 - Effect of Preservative Temperature on Average Treating Time. Average Rate of Treatment - 6 Pounds of Preservative per Cubic Foot of Wood.

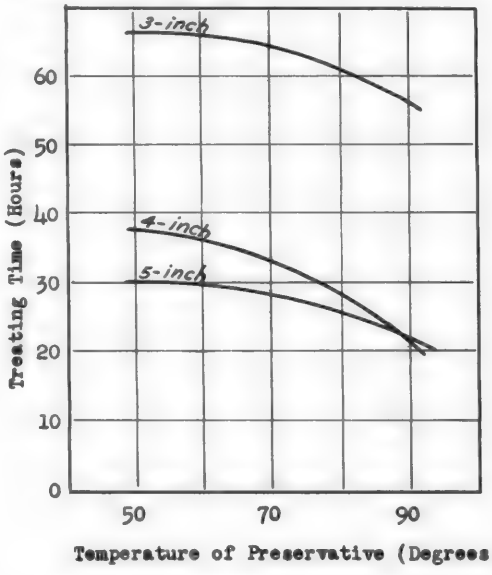

Table 3 - Treating time in hours as affected by post diameter, preservative, ring class, temperature of preservative, and difference between preservative temperature and wood temperature. Average rate of treatment - 6 pounds per cubic foot of wood.

	Preservative		Ring Class			Temp. of Pres.(°F)			Diff. of Wood Temp.(°F)			All
	CuN	Penta	5	10	15	50	70	90	10	20	30	
Post Diameter	Hours											
3	61	63	48	69	70	67	64	57	58	64	65	62
4	51	30	42	31	18	37	33	21	28	37	27	31
5	26	28	42	10	28	30	28	22	26	23	32	27
Diff. of Wood Temp.(°F)												
10	37	38	42	32	38	41	44	26				37
20	41	41	46	46	32	43	46	36				41
30	41	42	45	33	47	51	36	38				41
Temp. of Pres. (°F)												
50	45	45	52	39	43							45
70	42	42	46	40	41							42
90	32	34	35	32	33							33
Ring Class												
5	44	44										44
10	37	37										37
15	38	40										39
All	40	40										

A Modified Method for the Preservative Treatment of Southern Pine Fence Posts*

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DEMAND AND USE OF TREATED POSTS

THE PAST SEVERAL YEARS have witnessed an accelerated demand and use of preservative treated fence posts in lieu of untreated posts. Strong evidence of this can be detected in the annual statistics compiled and published by the American Wood-Preservers' Association and the Forest Service. Of primary importance in the sudden increase in the use of treated posts are high labor and material costs which put a premium on longer service life of the posts. Farmers are recognizing the unsound economics occasioned by the use of untreated, nondurable species for posts.

Coupled with the labor situation and the difficulty in obtaining naturally durable woods is the higher farm income realized in the past few years. Farmers have more money with which to buy treated posts or to treat their own. They can afford to pay the additional initial cost of a treated post if not excessive. Many farmers retain a sense of pride in their fence lines, particularly if they are boundary lines.

Although pressure treated posts are the best from the standpoint of preservative treatment, they are not generally available to farmers. Most commercial treating plants are located in urban centers making transportation costs prohibitive for all but those farmers located in close proximity. In addition, many commercial plants, for a number of reasons, are not too interested in treating fence posts. These factors have provided an impetus to various non-pressure methods, in particular to the cold-soaking process.

COLD-SOAKING PROCESS

With the advent of pentachlorophenol as a full-fledged wood preservative since the war, the cold-soaking process has become widely used. Probably the chief reason for the present extensive use of the cold-soaking method has been due to the considerable research done by the various State Agricultural Experiment Stations, Forestry Schools, and the Agricultural Extension Service. The work of these agencies has been considerably publicized in farm and forestry publications and as reports and bulletins. Most of the work done has been with pentachlorophenol although copper naphthenate has received attention.

Adaptable as it is for home treatments, cold-soaking presents certain problems which should be recognized. Only relatively few species can be treated and even in these so-called easily treated woods, good treatments are frequently not obtained. Pine has been the chief species used. One of the chief problems has been the proper regulation of the absorption of the preservative. An average retention of from six to eight pounds of preservative per cubic foot of wood is generally accepted as satisfactory for fence posts. There has not been complete agreement as to the correct length of treatment required to obtain this absorption. Many recommendations specify a blanket 48-hour soaking period. The Forest Products Laboratory states that "for round fence posts of easily treated woods, a soaking period of 48 hours produces good penetration." However, treating to a definite time schedule precludes control over the absorption of the preservative. Our experience in Louisiana indicates that for southern pine, a forty-eight hour treating period results in gross overtreatment. Instead of the desired six to eight pound average absorption, the posts will absorb from 12 to 16 pounds and higher per cubic foot. This is, of course, all right if expense is no object; however, it would be disastrous for a commercial operation basing its sales on the six to eight-pound treatment.

Cold-soaking is graduating from a strictly "on the farm" treatment. At present, we have four commercial plants employing this process in Louisiana, treating an estimated 50,000 posts per year. Control over absorption is a necessity for these operators and greatly desirable for all cold-soaking treatments. Such control can be gained by weight or volume measurements governed by the absorption desired. When the posts have absorbed a predetermined amount of preservative, they are removed from the treating tank. With southern pine, the time required to obtain proper retention varies from 15 hours down to 15 minutes.

*Presented at meeting of The Deep South Section, Forest Products Research Society, Shreveport, Louisiana, November 23, 1951.

Another problem of cold-soaking involves the type of petroleum oil used as the carrier. In order to obtain satisfactory treatment, relatively low viscosity oils must be used. These oils are frequently colorless and their use results in a post showing little evidence of treatment. The acceptance of these posts by a public, conditioned for years to the black color of creosoted material, has been understandably slow.

The most critical problem of cold-soaking involves the penetration of the preservative into the post. Too little attention has been given to the proper penetration. Even with easily treated woods, a shallow and erratic penetration is frequently the case, especially if the treating time is short. The minimum depth of penetration generally acceptable for satisfactory treatment is one-half inch. It is questionable whether the treatment is worth the expense if only a half-inch penetration is obtained as, in effect, the post consists of an easily ruptured shell of treated wood surrounding an untreated core. We have had evidence of early failure of such posts and this of course is unfortunate to all concerned.

LOW PRESSURE SHORT TIME TREATMENT

With these previously discussed problems of cold-soaking in mind, a treatment employing low pressures applied for a short period of time was designed and run on southern pine as a research project under the Louisiana State University Agricultural Experiment Station. The experimental pressure treating plant at the School of Forestry of the University was utilized for all treatments. This equipment is provided with the standard recording and indicating instruments as contained in commercial plants. The principal objective of the research was to determine the feasibility of treating southern pine posts with a low pressure for a very limited time. The effect on the retention and depth of penetration of the preservative of three pressures - 5, 10 and 15 psi. -- held for 5 and 10 minutes each was studied. It was hoped that a deep and uniform penetration with a reasonable net retention could be obtained. The experiment was designed to permit a factorial analysis of the effect the different pressures and times 27 used had on retention and penetration, and also their interaction. In addition, a study was made to ascertain what influence difference in relative density and growth rate of the posts treated had on the net retention.

DESCRIPTION OF MATERIAL USED

The work was conducted on round loblolly pine posts (Pinus taeda L.) cut from trees identified in the field from a dense second growth stand in St. Helena Parish, Louisiana. A total of 180 six-foot posts were cut in August 1950 and peeled by a Lowther chain-type mechanical peeler. The amount of heartwood in the posts was observed to be negligible. Immediately after peeling, the posts were open-stacked under light shade for six months of seasoning. At the time of treatment in April 1951, some of the posts showed signs of slight surface molding. Surface and end checking were not pronounced.

The preservative solution used was a 5 percent concentration of pentachlorophenol in Esso Standard Oil Company's No. 214 A heavy diesel fuel. This particular petroleum carrier was selected because of its darker color and higher viscosity than the practically colorless, lighter regular diesel fuel, usually recommended for cold-soaking.

PROCEDURE

Four posts were selected at random for moisture content determinations. The remaining 176 posts were divided at random into 12 treating charges labeled from A to L. Each charge consisted of 15 posts with the exception of charges A and B which had 13 posts each. Ring count and percent summerwood measurements were taken on each post. The volume of each post was calculated by Smalian's Formula, based on the basal area of the butt and top ends and the length in feet. The volume was also computed by the 'cone-frustum' formula for a number of posts. Inasmuch as no significant difference was found in volumes by these two formulas, Smalian's formula was used exclusively. The posts were weighed to the nearest hundredths of a pound on a Fairbanks-Morse scale immediately before and after treatment. Shortly following the treatment, borings were made on each post at the center to determine depth of penetration.

Two charges for each combination of pressure and time were treated -- six possible treatments, each replicated once. The preservative temperature was atmospheric for all charges, averaging 76° F., with a range of from 71° F. to 80° F. The cylinder was filled and emptied of preservative as quickly as possible. Filling time ranged from 2:05 minutes to 3:31 minutes. The time required to empty the cylinder ranged from 2:20 to 4:00 minutes. The treating period began after the cylinder was completely filled. All timing was done by an electric clock.

In the four posts used for moisture content determinations, three samples one inch thick were cut from each post: one from the center of the post and one approximately one and one-half feet from each end. The samples were

immediately weighed and dried down to constant weight in an electric oven.

RESULTS AND DISCUSSION

The results are given in the summary Tables 1 and 2. Table 2 is a summary by charges, two for each pressure and time used. Table 3 is a summary by treatments which shows the average retention and penetration obtained for each pressure - time combination used. The average retention for all 176 posts was 7.53 pounds per cubic foot and the average penetration of the sapwood was 85 percent. These averages are considered indicative of a very satisfactory treatment for fence posts. It is to be noted that the 15 psi. treatment for ten minutes resulted in complete penetration.

Factorial anaylses of variance were made of the effects of treating time and pressure on the retention and penetration in the 12 charges. The statistical test of treatment effect on retention showed that variations in the pressures used had a much greater influence than variations of the treating times. Pressure was significant to the five percent level of probability while the influence of time was not significant.

The statistical test of treatment effect on the penetration showed both pressures and treating times significant. Pressure was significant to the one percent level of probability and time to a five percent level.

It is generally thought that variations of the wood itself within a species might be expected to influence treatability. In this study, the influence of relative density and growth rate as expressed in number of rings per inch was considered. Correlation coefficients were computed to determine the relation, if any, these two wood variables had upon retention.

The number of growth rings per inch varied from a minimum of 2.0 to a maximum of 7.6, with an average of 5.1. The coefficient of correlation between retention and number of rings per inch was - 0.324, which indicates that only 10.5 percent of the variations in retention between posts was accounted for by difference in the number of rings per inch. This low correlation between retention and rings per inch is perhaps not surprising in view of the relatively short spread between the minimum and maximum number of rings encountered in the posts treated.

Differences in relative densities of the posts varied from a low of 27.42 to a high of 46.82 pounds per cubic foot. These densities were computed by dividing the initial weight of the post before treatment by its volume. The coefficient of correlation between retention and relative density was - 0.212, which indicates that only 4.5 percent of the variations in retention were dependent upon relative density. This is an even lower correlation than the number of rings per inch. The relative density of a post is the sum of both the amount of wood substance and the quantity of water contained in pounds per cubic foot volume. Although possibly not enough moisture content determinations were made to establish fully the range of moisture content, the low correlation coefficient between density and retention indicates that the differences in moisture content of the posts have little influence upon retention. Apparently, then, differences in retention are due to variables of the wood other than those studied.

The question of possible bleeding of the posts after treatment was considered, especially inasmuch as they were given a cold treatment. The posts were dry on removal from the treating cylinder and very little bleeding was observed after the posts were stacked outside in the sun.

Due to the fact that this method of treating involves low pressures and no heating facilities, the equipment necessary for treating posts in this manner need not be extensive nor too expensive. An ordinary reciprocating force pump would be adequate for obtaining the necessary pressures and for filling and emptying the treating cylinder, if gravity is not employed. The abbreviated length of treating time necessary to obtain sufficient retention and deep penetration would permit the treating of a large number of southern pine posts in a relatively short time.

TABLE 1

PERCENT OF MOISTURE CONTENT

Post No.	Size Vol. cu.ft.	Location of Sample Moisture Content (%) 1 1/2' from butt	Center	1 1/2' from top	Av./ Post
A	0.346	23.2	20.7	18.9	20.9
B	0.510	22.5	24.4	23.6	23.5
C	0.292	13.0	14.8	14.0	13.9
D	0.699	19.6	13.6	17.4	16.9
Average	0.461	19.6	18.4	18.5	18.8

TABLE 2

SUMMARY TABLE BY CHARGES

Charge No.	No. Posts Per Chg.	Treatment Time Min.	Treatment Pressure psi	Rings/ Inch	Summrd. Percent	Volume Cu. Ft.	Orig. Wt. Pounds Per Cubic	Treated Wt. Pounds Per Cubic	Retention Foot	Penetration Percent
A	13	5	5	4.9	37.7	0.403	35.34	41.98	6.34	54
B	13	5	5	4.6	38.1	0.410	36.26	43.65	7.39	56
C	15	5	10	5.0	40.3	0.362	36.94	44.84	7.91	83
D	15	5	10	5.4	37.7	0.339	34.99	41.14	6.15	96
E	15	5	15	4.9	38.3	0.369	35.38	44.41	9.03	93
F	15	5	15	5.2	36.3	0.351	34.91	42.17	7.26	92
G	15	10	5	5.3	36.3	0.322	33.60	39.58	5.98	84
H	15	10	5	5.0	35.7	0.336	36.92	44.31	7.39	78
I	15	10	10	5.4	38.7	0.376	37.23	43.72	6.49	94
J	15	10	10	5.1	37.3	0.367	37.68	44.84	7.16	81
K	15	10	15	5.2	36.3	0.359	37.39	46.65	9.26	100
L	15	10	15	4.6	37.7	0.379	36.73	46.33	9.60	100
Avg.				5.1	37.5	0.364	36.11	43.64	7.53	85

TABLE 3

SUMMARY TABLE BY TREATMENTS

Charge No.	Treatment Time Min.	Treatment Pressure psi	Retention lbs/cu.ft.	Penetration Percent
A & B	5	5	7.02	55
C & D	5	10	7.03	90
E & F	5	15	8.15	93
G & H	10	5	6.69	81
I & J	10	10	6.83	88
K & L	10	15	9.43	100
Avg.			7.53	85

Fire Retardant Doors*

OSCAR WITT, Roddis Lumber and Veneer Company, Marshfield, Wisconsin

SOLID-CORE WOOD DOORS can be used successfully where fire resistance is required. Wood doors are so adaptable to individual requirements of architechtural specifications and finish that they have practically monopolized the door market. Wood door manufacturers are, therefore, constantly conducting experiments to develop new constructions with which to meet the various building codes.

It is not difficult to produce a door which will hold up in the standard fire exposure test for a period of 20 minutes. Most of the present solid-core doors now on the market can pass this test. However, when the required resistance is raised to one half hour or more special constructions and special materials are required.

Experiments have developed processes which successfully impregnate lumber to such a degree that it will not ignite. When exposed to extreme heat or flame, the wood will char but the destructive effect of the flame will be confined to the area of contact. This renders the wood virtually non-inflammable and highly resistant to the penetration of flame.

In order to develop fire retardant lumber it is necessary to inject chemicals into the lumber. These chemicals must be injected under pressure so that a thorough impregnation is accomplished. Formulas which are being used today employ water-soluble chemicals. As a consequence, the treated lumber contains an excessive amount of moisture. This excessive moisture must be removed before the lumber can be used in the construction of the solid-core flush door.

The removal of the excessive moisture must be very carefully performed by an experienced dry kiln operator. Kiln temperature in excess of 140° F. will prevent the chemicals from remaining uniformly precipitated within the entire cell structure and will result in having most of the chemicals deposited on or near the surface of the wood. After the lumber has been impregnated and properly kiln dried, it should be stored in a dry place.

Extreme care must also be exercised in the gluing of fire retardant lumber. If the gluing is done in a hot-plate press, the minimum amount of heat that can be utilized and still combine with a short pressing cycle is of prime importance.

To add to the complications, some species of lumber lend themselves much more readily to treatment than do some others. As an example, California redwood will absorb and distribute the chemicals uniformly. In contrast, pine will not always develop a complete impregnation. This is particularly true of yellow pine and also to a lesser degree of ponderosa pine.

During the treating and drying processes, the wood has a tendency to become discolored. For this reason, the faces of the door are made from standard thickness veneers which have not been treated. The standard thickness of face veneer is seldom in excess of 1/20 inch and in most cases is only 1/28 inch.

Some of the better known constructions are as follows:

1. Solid-core flush door which has a solid softwood core made from strips which have double tongue-and-groove side joints and single tongue-and-groove end joints. These softwood core strips are not treated for fire resistance. The core is banded on all four edges with two 3/4-inch hardwood edge strips which are double tongued-and-grooved to the core and to each other. The outer edge strip is fully fire retardant. Into the core assembly, a lock block made of fully impregnated material will be inserted. This lock block can be splined into the core at any designated place. This core assembly is then covered on both sides with a blanket of 1/16-inch-thick woven asbestos cloth. This, in turn, is covered by 1/20-inch-thick hardwood cross bandings and the previously mentioned standard-thickness face veneer. Phenolic resin glue is used in all bonding operations.

2. Solid-core flush door in which the entire assembly with the exception of the face has been fully impregnated for fire retardant qualities. The core is made from a species that is most adaptable to impregnation and is banded on all four edges with 3/4-inch thick fully treated hardwood edge strips. The core assembly is then covered on both sides with fully treated cross banding and this, in turn, is covered with non-treated faces.

*Presented at meeting of Midwest Section, Forest Products Research Society, Oshkosh, Wis., September 20, 1951.

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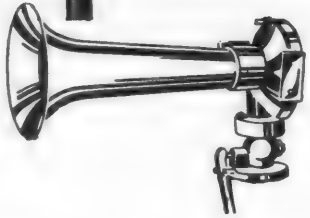

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3. Solid-core flush door which has a mineral composition core which is flame proof. The core is banded on all four edges with 3/4-inch-thick fully impregnated hardwood edge strips. This core assembly is then covered on both sides with non-treated 1/16-inch-thick hardwood veneer crossband and this in turn is covered by standard-thickness non-treated face veneer. Phenolic resin glue is used to bond cross banding to the core and to the face.

Most fire retardant doors use phenolic resin in the bonding operations. In some instances manufacturers have foundthat resorcinol glue offers greater resistance to flame. In many cases hide glue produced the better bond especially when treated wood is bonded to treated wood. However, neither of these glues lend themselves to economical production as readily as does the phenolic type.

Please remember that all of the foregoing is based on solid core veneered flush doors and not on any other types.

1534. LAWTON, E. J., BELLAMY, W. D., HUNGATE, R. E., BRYANT, M. P., and HALL, E. **Some effects of high velocity electrons on wood.** *Science* 113 (2936), 1951 (380–2). 7 refs. [General Electric Research Laboratory, Schenectady, New York.]

Irradiation of Basswood with high-velocity electrons altered its structure in such a way that some of the insoluble carbohydrate components became available to rumen bacteria. Possible interpretations of this result are offered. [Cf. *For. Abstr.* 13 (p. 115).]

1561. BOCK, E. Prüfung von Holzleimen. Die Bestimmung der statischen Festigkeitseigenschaften der Leimverbindungen. **[Testing of wood glues. Determination of the static strength properties of glued joints.]** *Holz Roh- u. Werkstoff* 9 (2), 1951 (62–71). 12 refs. [G.g.] P.R.

Discusses and analyses the effect of the glue line on various static strength properties of wood. A test piece has been developed for accurate measurements of tensile strength along the grain; also a new simple method of determining the splitting strength, which gives also the transverse strength value. Compression across the grain can always be neglected, and that along the grain should be taken into consideration only in exceptional cases. The shearing strength can be estimated only on the basis of careful tests. Other strengths (bending, torsional, and buckling) have no significance for the testing of glues.

1500. SMEATHERS, R. **A comparative study of some of the more important mechanical and physical properties of Trinidad and Burma grown Teak (*Tectona grandis*).** *Inst. Pap. imp. For. Inst., Oxf.* No. 27, 1951. pp. 19. Price 2*s.* 6*d.*

The timber now being grown in the Teak plantations of Trinidad is in no way inferior to that represented by a sample of Burma-grown Teak obtained from a commercial source.

The following abstracts have been selected from a much larger number in Forest Products and Utilization Abstracts, Vol. 13, No. 2, Dec. 1951, with the kind permission of the Editor, the Director of the Commonwealth Forestry Bureau, Oxford, England. Forest Products and Utilization Abstracts are published quarterly, by the Commonwealth Agricultural Bureaux, as a separate reprint of decimal sections 3, 7, and 8 of Forestry Abstracts, for the facility of those interested chiefly in the field of wood utilization. The Utilization Abstracts contain about 1200 classified titles and abstracts per year, from literature in some 30 languages and cover all aspects of forest utilization from cutting and extraction through marketing, mechanical and chemical processing to minor forest products.

Readers wishing information in addition to that given in these abstracts must consult the original article referred to. Copies or additional information cannot be supplied by F.P.R.S. or the abstract journal.

1469. **Forest industries of Brazil.** Ministry of Foreign Affairs, Cultural Division, Rio de Janeiro. 1949. pp. 112.

Notes on the following industries, with production statistics: oils (fixed), waxes, gums, resins and essential oils, timber (giving the properties and characteristics of some Brazilian woods), cellulose, textile fibres, tannin, vegetable insecticides and medicinal plants.

1501. GRAF, S. H. **Ignition temperatures of various papers, woods and fabrics.** *Bull. Ore. Engng. Exp. Sta.* No. 26, 1949. pp. 69. 19 refs. P.R.

The bulletin is based on data obtained with semi-automatic apparatus carefully designed to give conditions easily duplicated and comparable to those that could exist in a storage warehouse or a similar building. The substances were tested under conditions of variable specimen weight, variable heating rate, variable air flow, variable atmosphere composition, and variable humidity, in an effort to obtain the minimum ignition temperatures. The general trend was toward lowered ignition temperature with increase in sample size, with decrease in heating rate, and with increase in oxygen concentration of the

1526. JAYME, G. Über die Bedeutung des Zugholzanteils in Pappelhölzern. **[The significance of tension-wood in Poplar.]** *Holz Roh- u. Werkstoff* 9 (5), 1951 (173–5). [G.g.] P.R.

Presents the results of a chemical investigation of Poplar tension wood compared with those obtained for normal wood. Tension wood contained more raw cellulose (and pure cellulose), but less lignin, less hypothetic total pentosan, and less soluble hemicellulose than normal wood. The specific gravity (oven-dry) of tension wood was 17·5% greater than that for normal wood. No difference in fibre length between the two woods could be found. When peeled, Poplar with a high tension-wood content yields veneer with a 'wavy' surface. *From author's summary.*

1543. RUNKEL, R. O. H. Zur Kenntnis des thermoplastischen Verhaltens von Holz. **[Thermoplastic behaviour of wood.]** *Holz Roh- u. Werkstoff* 9 (2), 1951 (41–53). 131 refs. [G.g.] P.R.

A survey of world literature on chemical processes in the system wood/water/heat, followed by a discussion of the various transformation possibilities of the hemicelluloses and of the lignin/carbohydrate complex, including the hydrolytic break-up and the subsequent formation of plastic substances by condensation. Suggests a new method for the investigation of chemical processes during plasticizing by heat, which consists in treating the material in a gas-tight apparatus which prevents the volatile products from escaping. The apparatus (a kind of autoclave) should be packed with wood material which is subjected to hydraulic pressure. The generated volatile products fill out the pores (7–20% of the volume), and the conditions of the polymerization and condensation processes resemble those in pressure synthesis.

1549. Holzbearbeitungsmaschinen 1951. **[Woodworking machines, 1951.]** *Holztechnik* 51 (4), 1951 (98–127, 130). [G.] P.R.

Description of the exhibits of 94 German manufacturers of wood-working machines in the 'Technische Messe' at Hanover, 29 April–8 May 1951. The illustrations and descriptions comprise thicknessing machines for planks, a large drum polishing machine, automatic charging devices for plywood presses, peg-hole boring machines, scraper and milling machines, squaring saws, glue spreaders, hydraulic presses, semi-automatic polishing machines, high-temperature seasoning apparatus, automatic veneer clippers, band saws, circular saws, an electric moulding machine, and veneer peelers.

1547. HENRIKSEN, E. K. **Stress distribution in the continuous chip—a solution of the paradox of chip curl.** *Trans. Amer. Soc. mech. Engrs.* 73 (4), 1951 (461–6). P.R.

The 'chip' passes along the tool face for a certain distance before it leaves the tool, then curls. It is suggested that a sudden drop in pressure occurs at the point of ultimate contact, which combines with a single force at this point. The physical origin of this system of forces is explained by surface roughness of the tool, which explains the sharp boundary line for the area of wear on the tool face. Distribution of pressure between chip and tool follows an exponential law. Methods of stress analysis are explained that should be useful in further investigations. *From author's summary.*

1562. KNIGHT, R. A., DOMAN, L. S., and NEWALL, R. J. **Durability tests on plywood adhesives.** *Wood* 16 (6), 1951 (210–3).

An interim report on a 10-year experiment in progress at the Forest Products Research Laboratory, Princes Risborough. A large range of adhesives used in Beech plywood is being tested under 4 types of exposure: (1) stored in a normally heated workshop, (2) exposed to the weather on racks facing south in an open field, (3) stored in an open-sided shed and dipped for a moment in water once a month, and (4) immersed in fresh water in tanks standing in the open air. The results after the first 5 years of exposure are presented.

1565. EICKNER, H. W., and BLOMQUIST, R. F. **Adhesives for bonding wood to metal.** *Rep. U.S. For. Prod. Lab., Madison* No. *R*1768, 1951. pp. 15 + 1 photo, 1 dgm. 4 refs. P.R.

Describes some of the types that are available, the conditions of bonding that should be observed with them, and the strength and durability of bonds obtained when these adhesives are properly used. Includes a list of 34 selected (American) articles on wood-to-metal and metal-to-metal bonding.

1570. SELBO, M. L. **Summary of information on gluing of treated wood.** *Rep. U.S. For. Prod. Lab., Madison* No. *R*1789, 1950. pp. 12. 4 refs.

Results obtained in various studies are correlated and summarized and an attempt is made to frame recommendations. The following preservatives and fire-retardants are dealt with: coal-tar creosote, copper naphthenate, Wolman salts, Celcure, zinc meta-arsenite, chromated $ZnCl_2$, $(NH_4)H_2BO_4$, $(NH_4)_2HPO_4$, $(NH_4)_2SO_4$, H_3BO_3, $Na_2B_4O_7$, $ZnCl_2$, and mixtures of two or more of these.

1585. PECK, E. C., and SELBO, M. L. **Comparison of Redwood and flat-grained Yellow-Poplar for cores in furniture panels.** *Rep. U.S. For. Prod. Lab., Madison* No. 1785, 1950. pp. 10 + 13 photos, 1 dgm., 11 tbls. P.R.

Vertical-grained Redwood compares favourably with flat-grained Yellow Poplar as core material for high-quality furniture panels. Under the conditions tested, panels with vertical-grained Redwood cores remained flatter and developed fewer and smaller face ridges and grooves with changes in moisture content, than panels with flat-grained Redwood or Yellow-Poplar cores. Although panels with flat-grained Yellow-Poplar cores generally cupped more than panels with flat-grained Redwood cores, the development of ridges and grooves was less for the Yellow-Poplar cores. Core strips as wide as 10 in., and including bands of sapwood, had no detrimental effects where vertical-grained Redwood was used. Flat-grained Redwood core strips containing sapwood developed more and larger face grooves and ridges than panels with any of the other types of core. *Authors' summary.*

1587. NEUSSER, H. Überlegungen zu den Abfällen der Furnierschälerei. **[Veneer-peeling waste.]** *Mitt. öst. Ges. Holzforsch.* 3 (2), 1951 (16–21). [G.] P.R.

According to available data, *ca.* 34·4% by volume of air-dry Beech peeler logs is converted to full-size and small plywood; shrinkage and compression loss is responsible for 19·3%, leaving 46·3% as waste material, viz. 18% large waste (end discs and log cores), and 28·3% from sawdust, small veneer sheets and plate-like pieces. Out of the waste, ca. 13·9% is air-dry, while 32·4% has a moisture content of 40–50%, which must be considerably reduced before use. One of the best methods of using small veneer is by scarf-jointing. It is also possible to use log cores for veneers. Only ca. 30% of Beechwood log cores are free from heart-shakes, and ca. 20–40% have short shakes. It is possible to peel such cores (in half-lengths in a special peeler) from 12 down to 6 cm. diameter. A machine of this kind is made by the German firm Vereinigte Furnier- und Sperrholzfabriken. They may also be sliced in machines, 3 sizes of which are made by German manufacturing firms.

1588. KRPAN, J. Iskorišćenje bukovih trupaca za ljuštenje. **[The utilization of Beech logs for peeling.]** *Šum. List* 75 (3/4), 1951 (121–42). 12 refs. [Croat.croat.e.]

The recovery from Beech peeler logs in the production of plywood in Jugoslavia is *ca.* 40%. The waste is accounted for by: total losses at peeler 29% (varying from 8 to 50% as the log diameter decreases), veneer clipping waste 10%, veneer drying loss 6%, veneer trimming waste 4%, plywood trimming waste (circular saw) 4%, loss due to the sanding (or planing) of plywood faces 5%. The effect on the % of waste of stem curvature, non-circular section, excentricity of log, and knot size is analysed. Out of the 60% total waste, 6% represents drying loss, some 4% is utilized for packing and internal transport, while *ca.* 50% is used as fuel.

1611. GARLAND, H. **Possibilities for the production of wood briquette stoker fuel in Northern Michigan.** Forest Products Research Division, Michigan College of Mining and Technology, Houghton, Mich. 1950. pp. 22. P.R.

Waste wood of Northern Michigan species can be briquetted by the Pres-to-log process, the technological and economic aspects of which are discussed.

1617. SCHULZE, B., and STAMER, J. Einwirkung von Holzschutzmitteln auf die Holzfaser. **[Effect of wood preservatives on wood fibre.]** *Wissenschaftliche Abhandlungen der deutschen Materialprüfungsanstalten, Berlin* 2 (7), 1950 (113–23). 11 refs. [G.g.] P.R.

Compressive-strength tests were made on Beechwood test blocks, untreated or treated with one of

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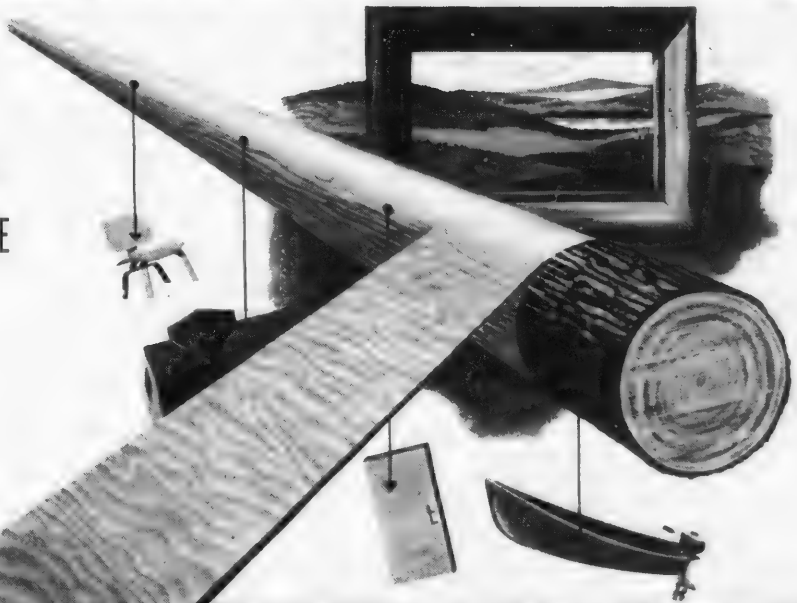

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122 various preservatives or concentrations of a preservative, over periods in most cases up to 24 months. After 18 months, 9 preservatives were found to have lowered, and 12 to have increased the strength. $ZnCl_2$ (5%) gave after 60 months a strength decrease of *ca.* 30% (the accepted scattering being 20%). Contrary to current belief, the ammonia-containing Cu and Zn solutions, or mixtures of $ZnCl_2$ with NaOH had hardly any weakening effect. Silicofluorides cause an increase of strength. No increase appeared to be due to the effect of oil treatment.

1631. **Lyctus investigations.** *Rep. For. Prod. Aust. 1949/50*, 1950 (23–4).

It has been found that the momentary dip treatment of green veneer in cold solutions of H_3BO_3 or borax is entirely successful in practice for the prevention of Lyctus attack. The addition of preservatives to the glue is recommended for plywood, which will thus be effectively sealed on all surfaces.

1646. NEWKIRK, T. E. **Fire tests on untreated and treated Spruce in ventilation doors [in mines].** *Canadian Mining and Metallurgical Bulletin, Montreal* 42 (452), 1949 (642). D.S.I.R.

Results of tests on small-scale models indicated that ventilation doors treated with a 17% solution of chromated $ZnCl_2$ will remain useful for ¼ hr. exposed to a temperature of 1,790° F., ¾ hr. at 1,350°, and 1½ hr. at 1,025°. Untreated doors failed in 7 min. and doors treated with a 4% solution in 12 min. at 1,700°. [Cf. *For. Abstr.* 12 (No. 584).]

1664. SMITH, W. J. **Changes in circumferential dimensions of Douglas Fir poles during seasoning.** *B.C. Lumberm.* 35 (6), 1951 (44–6).

Circumferential measurements of 100 mountain-type Douglas Fir poles, 25 ft. long, were made at the butt, at 6 ft. from the butt, and at the top, when green, after 6, 9 and 12 months' air seasoning, and at the end of the 12 months' seasoning after butt-soaking to the ground line (5 ft. from the butt). Results are given in graphs and tables. They indicate that the average reduction in circumference from the green dimensions will not exceed 1% at 6 ft. from the butt after air seasoning. The average reduction in bending strength will not exceed 3%. The % recovery after soaking was 84·5 at butt and 16·2 at 6 ft. above butt. If Douglas poles have the required circumferential measurements at 6 ft. from the butt when green, it is not necessary to re-measure them at any stage of seasoning.

1673. STEVENS, W. C. **The seasoning of wood at temperatures above the boiling point of water.** *Wood* 16 (7), 1951 (260–2). [Forest Products Research Laboratory, Princes Risborough.]

Discusses methods of seasoning by radio-frequency, vapour, super-heated steam and vacuum drying.

1698. PASCOE, T. A., and SCHEFFER, T. C. **Jack Pine pulpwood deterioration in yard storage.** *Pulp Paper Mag. Can.* 52 (7), 1951 (184, 186, 189, 190, 193, 196–7). 11 refs.

A quantity of Jack Pine pulpwood from a single tract in Wisconsin was stored in typical yard conditions for 21 months. The material was either rough or peeled, and either treated with a 5% solution of Dowicide G, or untreated. Records were kept of the rate of loss of moisture and density and of the progress of decay in the pulpwood, and pulping tests were carried out during the period. Results, given in graphs and tables, apply only to the untreated wood, as no significant differences were found between treated and untreated material. The % loss of volume and certain visible characteristics of the wood (defined, and classed as 1–4) are used together to give a decay index. Rough wood showed much greater damage from decay than peeled wood, with a loss in pulp yield of up to 10% calculated on a wood volume basis; the rate of damage was greatest during the early period of storing. Pulp strength decreased with increasing storage time. There was only negligible decay in peeled wood during the period, but some loss of pulp strength occurred, increasing with length of storage. Immediate use of Jack Pine after felling is recommended for highest possible pulp quality. If storage for more than 4–6 months is necessary in hot weather, the wood should be peeled.

1707. MACDONALD, M. D. **Manufacture of consolidated products from wood residues.** *Paper Tr. J.* 132 (23), 1951 (20, 22–4, 26, 28). 6 refs. P.R.

Describes in detail the dry-process manufacture of boards from wood waste. The optimum moisture content of the wood waste (shavings and the like) is 4%, the optimum size of wood particles falls within 0·05 to 0·25 in. mesh, and the minimum quantity of binder used is 2·5% of the weight of the board; no useful purpose is served by increasing the binder content above 3·5%. The mid-thickness temperature during pressing should reach 250° F., a pressure of 200–600 lb./sq. in. being desirable for most products, and pressures up to 5,000 lb./sq. in. for die-pressed materials. The moisture content of wood waste is maintained at the proper level, and diffusion of the binder into the material facilitated, by the use of a water-soluble phenol-formaldehyde resin binder that is sprayed on the wood-waste particles; the spraying apparatus is illustrated and described. The boards can be either unfaced or faced with paper, veneer, or cloth. Strength tests show that the modulus of rupture drops sharply when the resin content falls below 2%, rises steadily up to 6% resin content and then tapers off. Water-absorption tests show that for boards with a binder content of 2% or less, the absorption rate is high, and that it decreases with increased binder content up to 3·5%, any change beyond that point being insignificant.

1720. KURTH, E. F., and HUBBARD, J. K. **Extractives from Ponderosa Pine bark.** *Industr. Engng. Chem.* 43 (4), 1951 (896–900). 18 refs. P.R.

Ponderosa Pine bark taken from sawlogs 24–36 in. in diameter at Sisters, Ore., are found to contain ca. 25% extractives. Tannin to the extent of 5·6–11·4% and wax equivalent to ca. 5% of the dry weight of the bark were obtained. The wax is composed of fatty alcohols, fatty acids, and resin acids. A new flavonoid was isolated. *From authors' summary.*

1708. FARBER, E. **Hardboard from wood.** *Paper Tr. J.* 132 (18), 1951 (22, 24, 26, 28). 6 refs. P.R.

Describes the development of a special hardboard, primarily designed for use as the face material of wirebound boxes, from hardwood waste. A new method of converting hardwood waste into pulp was used, giving a pulp yield of 85–90%. From this material, hardboard of medium density and hardness was obtained. Melamine (3%) and gelatinized wood (gelwood, 10–15%) were used as binders. The quality of boards was improved by the addition of 20% of softwood kraft pulp.

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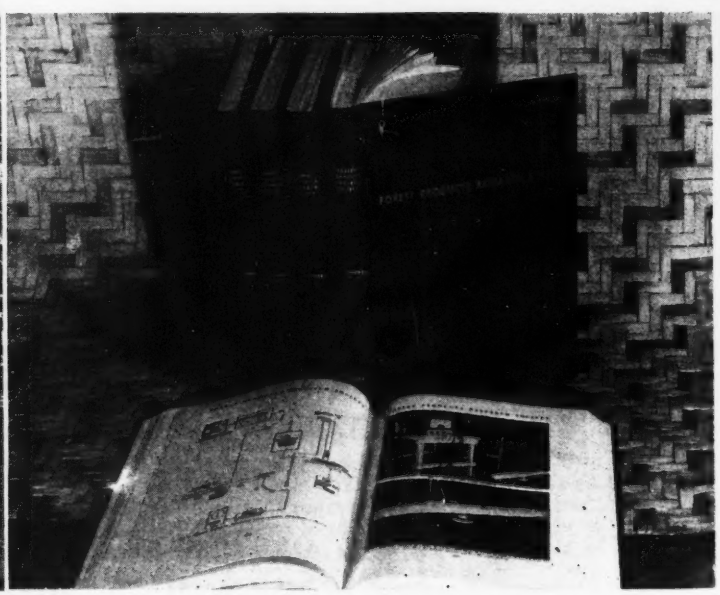

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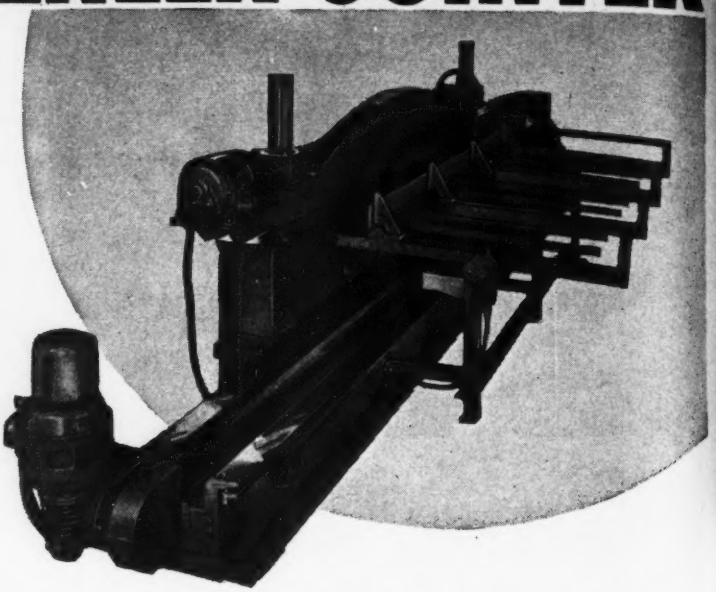

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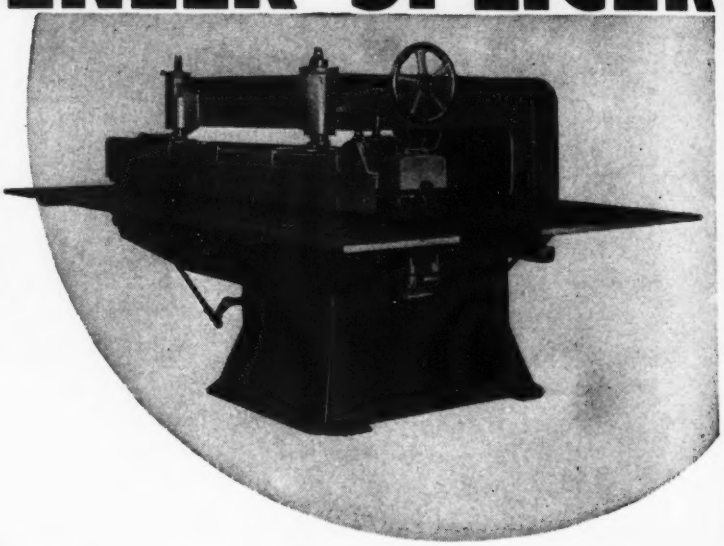
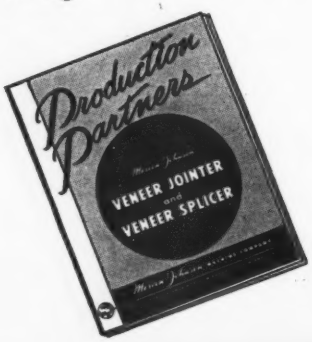
90″, 102″, 126″, 150″, 200″, 212″.

Mereen-Johnson VENEER SPLICER



Precision tapeless joints—self-adjusting for varying thicknesses. About the only adjustment required by this machine is speed variation, regulated from 15 to 120 feet per minute. Either glue or catylist is applied smoothly and evenly by the revolving glue disc at the infeed end. Chains are self cleaning.



Send for the **JOINTER-SPLICER** *Bulletin*

Mereen-Johnson MACHINE COMPANY

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